Flood Impact Assessment

2 Macpherson Street, Warriewood

59917042

Prepared for
Meriton Group

5 December 2019

Cardno
Shaping the Future

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Executive Summary

In order to determine and manage the flood impacts associated with the proposed development of 2 Macpherson Street, Warriewood a flood impact assessment for the site has been prepared. Hydraulic modelling of the site has been undertaken to determine the potential impacts of the development within the floodplain and to ensure that the impacts and risks posed by the development of the site are understood.

Based on the analysis undertaken the following outcomes have been established:

- The final fill level of all dwellings onsite is 4.9 mAHD, which is above the PMF flood level and in excess of the defined flood planning level for the site (1% AEP climate change and sea level rise (0.9m);
- Up to and including the extreme events, no adverse flood impacts in excess of 20 mm occur upstream and downstream of the site.
- There is only a minor physical loss (<-145 m^3) of flood storage occurs onsite in events up to the 1% AEP with climate change. This loss does not result in any impacts external and internal of the site and is therefore deemed acceptable.
- Shelter-in-Place is a viable emergency response option and does not result in an increase in risk to life if appropriately incorporated into the development.

Overall, the proposed development demonstrates compliance against Council's flooding conditions.

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Glossary

Average Recurrence Interval (ARI)	The long-term average period between occurrences equalling or exceeding a given value. For example a 20 year ARI flood would occur on average once every 20 years.
Annual Exceedance Probability (AEP)	The probability of an event occurring or being exceeded within a year. For example a 5% AEP flood would have a 5% chance of occurring in any year. An approximate conversion between ARI and AEP is provided.

AEP	ARI
63.2 %	1 year
39.3 %	2 year
18.1 %	5 year
10 %	10 year
5 %	20 year
2 %	50 year
1 %	100 year
0.5 %	200 year
0.2 %	500 year

Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Flood	The covering of normally dry land with water from a stream, river, estuary, lake, dam, major drainage and/or due to super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
Freeboard	A height added to flood levels to provides reasonable certainty that the risk exposure accepted by deciding on a particular flood is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, driveway crest levels, etc.
Probable maximum flood (PMF)	The largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain.

1 Introduction

Cardno (QLD) previously issued the 'Flood Impact Assessment, 2 Macpherson Street, Warriewood (ref: 59917042/Rev1) dated 13 September 2017. Subsequently, Council issued a Request for Further Information (RFI) as per an email correspondence dated 22 December 2017. The RFI requested an assessment of open entrance conditions on local flood behaviour for the full range of design events listed in Table 6 (Refer to Section 3.5.3 of this report), based on both interim and ultimate creek design conditions.

In response to Council's first RFI, a revised flood impact assessment (FIA) report (Rev2) has submitted to address the relevant queries. Due to the lack of complete design of the final creek works at that stage, the assessment considered the interim creek design conditions (incorporating the proposed design associated Macpherson Street Upgrade).

An additional RFI was issued in response to the *Cardno FIA Rev2*. Council reviewed the documentation provided as part of the rezoning submission and, concerning flooding and found deficiencies in reported information. As a result, the addendum flood impact assessment was issued, '2 Macpherson Street, Warriewood – Addendum Flood Impact Assessment (ref: 59917042\Lt02) dated 27 February 2018. The addendum provided further advice concerning the deficiencies noted in the RFI and provided Council with sufficient information to confidently assess the applications with regards to flooding.

This version of the report, due to the large changes in design and for readability incorporates the addendum findings into the report. Appendix C of this report also provides a Flood Emergency Management Plan (*59917042 R001 Rev4 Warriewood FEMP,* Cardno 2018), which should be utilised in conjunction with this report.

1.1 Site Characteristics

The proposed development site is located at 2 Macpherson Street, Warriewood. The site comprises approximately 2.1 Hectares of land at 2 Macpherson Street (the site) in Warriewood Valley. Legally, the site is described as Lot 25 Section C in DP5464 and is shown in Figure 1-1.

The parcel of land is of an irregular shape has a 120 metre frontage to Macpherson Street to the south. A central portion of the site has been raised and levelled and is currently surrounded by undeveloped land. Levels across the site range from 1.4 mAHD in the northern section of the site (within the creek) to a high point of 3.7 mAHD within the central portion of the site.

Figure 1-1 Site Locality Plan (Source – Urbis)

1.2 Relevant Documents

The report has regard to the following documents:

- Floodplain Development Manual by NSW Government (April 2005);
- Pittwater Local Environment Plan (LEP) 2014; and
- Warriewood Valley Urban Land Release Water Management Specification (WMS, 2001)

2 Flood Behaviour

Floods are discussed in terms of how likely the flood is to occur or be exceeded in any given year. This is called the Annual Exceedance Probability or “AEP”. For instance, a flood that occurs on average every 100 years has a 1% chance of occurring in any given year. Larger floods do occur, although they have less chance of occurring in any given year.

The site is subject to both flooding from Narrabeen Creek and the Narrabeen Lagoon Floodplain. Results from the Narrabeen Lagoon Flood Study (WBM BMT, 2013) indicate that Macpherson Street in its current arrangement is overtopped in the 1% AEP due to the flow present in Narrabeen Creek and the influence of backwater from Narrabeen Lagoon. In the PMF event the area is significantly inundated due to the levels present in the Narrabeen Lagoon Floodplain.

Currently Macpherson Street is in the process of being upgraded. This will result in the roadway having a level of immunity greater than 1% AEP with 30% climate change and 0.9 m sea level rise. The road will not be trafficable in the PMF event however.

For the purposes of the analysis undertaken, it is considered that Macpherson Street upgrade has been completed, as the development will not occur prior to this scenario.

2.1 Flood levels

Each Local Government Authority (LGA) generally defines a flood planning level based upon an AEP with an allowance for freeboard to cater for uncertainties. In the Northern Beaches LGA within the Pittwater LEP, where the proposed development results in an *intensification of development* the flood event that is utilised as the flood planning level is the 1% AEP with 30% climate change and 0.9 m sea level rise. A freeboard of 0.5 m above this level is expected for all proposed dwellings.

The final fill level of the dwellings onsite is above 4.9 mAHD which is above the PMF flood level. As a result the dwellings onsite will not be inundated by floodwaters in a 1% AEP with 30% climate change and 0.9 m sea level rise or smaller floods. The defined flood level for this site in this event is 3.79 mAHD.

2.2 PMF Flood Event

The PMF Event is largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation coupled with the worst flood producing catchment conditions. The PMF event is generally considered to have an equivalent AEP of between 0.0001% and 0.00001% AEP.

Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain.

The purpose of utilising the PMF flood event within an assessment is to ensure the residual risk (that is the risk that exists once the flood immunity of a development is exceeded) that is present onsite is considered and planned for.

Figure 2-1 provides an overview of the flooding experienced within the Narrabeen Lagoon area at a catchment level in the existing flood conditions. In the PMF flood event over 3000 properties are flood affected, with almost 1400 dwellings experiencing over floor flooding (Cardno, 2016).

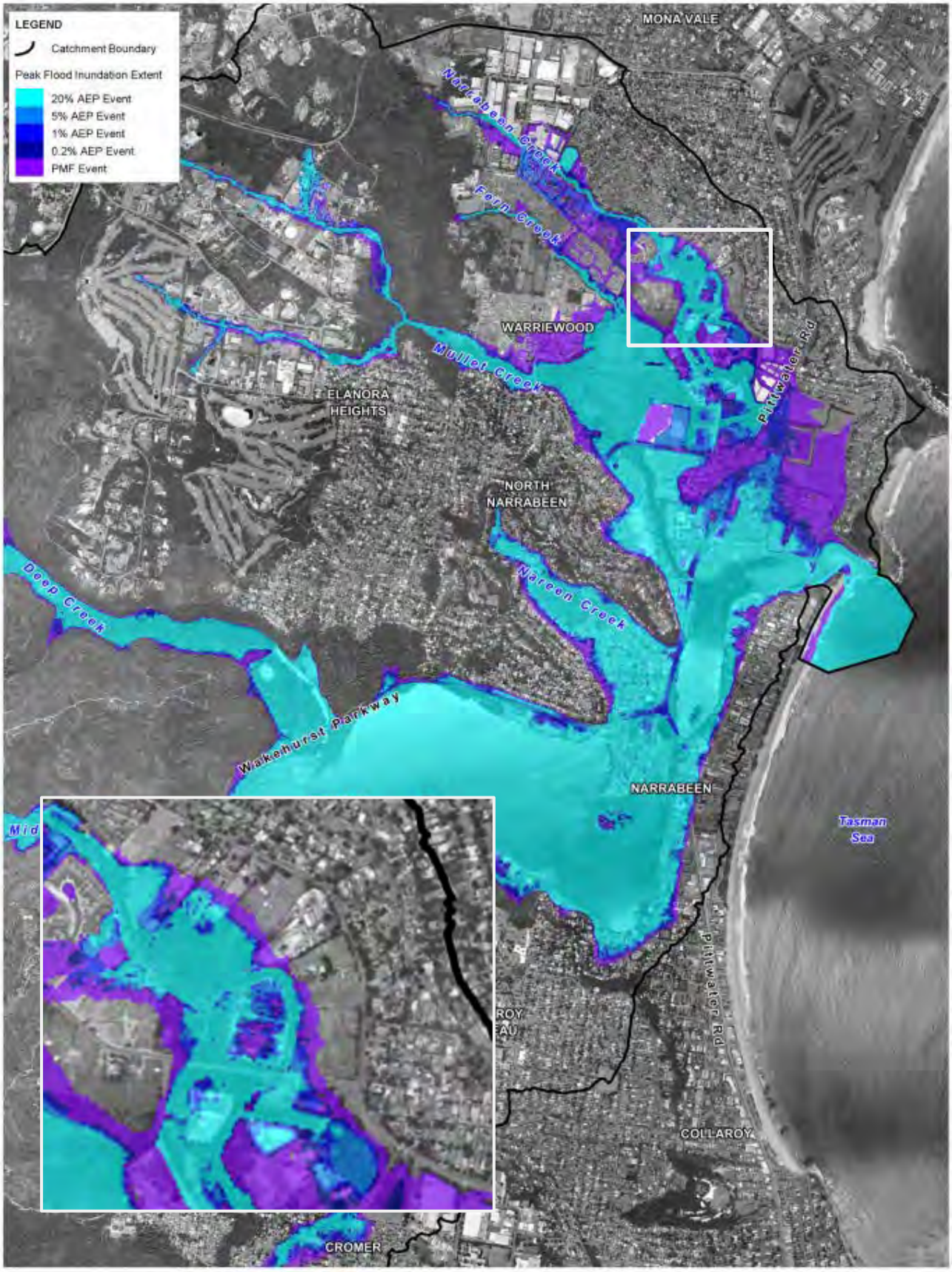


Figure 2-1 Peak Flood Extent – Catchment Derived Events ***(Source: Narrabeen Lagoon Flood Study, BMT, 2013)***

3 Proposed Development

3.1 Introduction

The development of the site will take into account the flood affectation of the site. Given that the majority of the site is Low Flood Hazard in the 1% AEP (as evidenced in the Narrabeen Lagoon Flood Study, 2013), development of the site will be confined to those Low Flood Hazard areas to connect the site to the Macpherson Street upgrade and the associated Narrabeen Creek works. The only works outside this Low Flood Hazard Area are being undertaken as part of the Macpherson Street upgrade, which provides access to the site from the new road level (which is approximately 2.2 m higher than the existing road level at the site entrance).

In the PMF event it is noted that under existing landform conditions the site sits within a high hazard region. the Flood Emergency Management Plan (Cardno, 2018) discusses the treatment measures proposed to ensure risk to life is minimised.

The proposed development is to consist of 22 dwellings, all of which will be two storey. **Figure 3-1** shows the indicative site and lot arrangement.

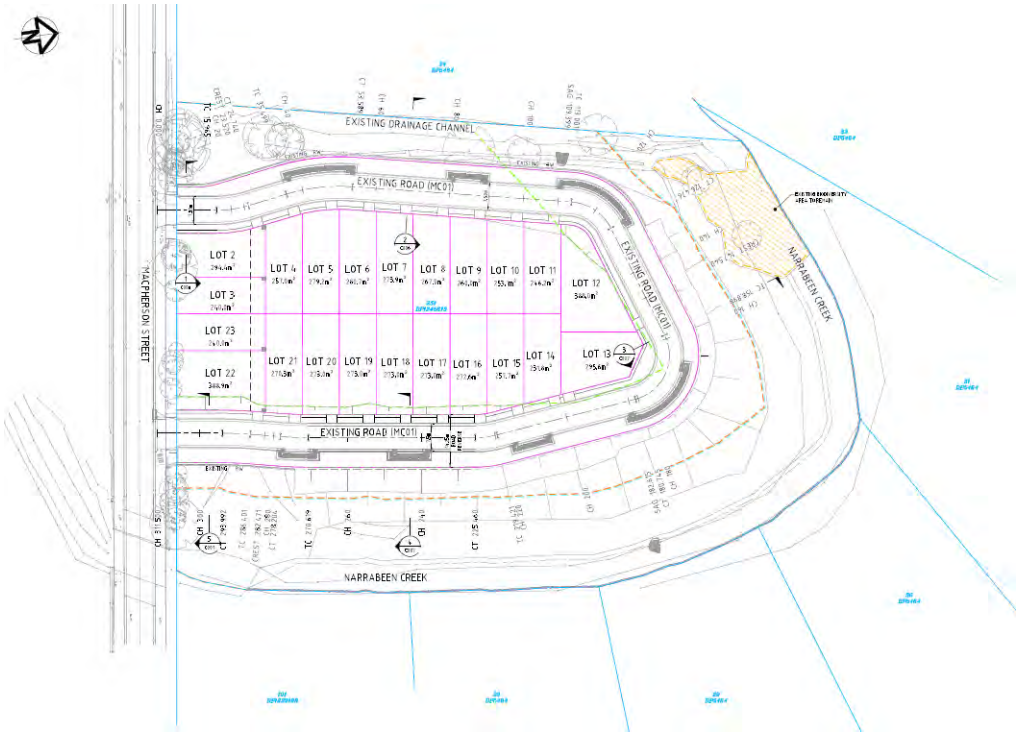


Figure 3-1 Indicative Lot and Site Layout

3.2 Fill Levels

The final proposed floor levels and fill levels are provided on drawing number C005 provided in Appendix A. The following criteria are addressed within this earthworks plan:

- The development level should be above the planning level (above the 1% AEP with 30% climate change plus 0.9m sea level rise). The flood planning level for this site is considered to be 4.9 mAHD based on current flood mapping of the site;
- No adverse impacts upstream and downstream of the subject site (no impacts greater than 20 mm recorded in any modelled event); and
- A minor loss of flood storage <10% up to the 1% AEP with 30% climate change plus 0.9m sea level rise

The finished floor level of the development is set to be above 4.9 mAHD. The internal roadway within the development ranges from 3.50 mAHD to 4.10 mAHD. The internal roadway has 1% AEP with 30% climate change and 0.9 m sea level rise immunity.

3.3 Integration with Stormwater and Water Cycle Management Systems

The water quality requirements for the site are nominated in Pittwater Council 2001, *Warriewood Valley Urban Land Release Water Management Specification (WMS)*. The water quality objectives are provided below:

"Specific standards have been developed for in-sector monitoring applicable to wet or dry weather stormwater discharge concentrations. However, as a minimum, a 'no worsening' of existing runoff quality is required".

A Water Management Strategy (Atl, 2018) provided within the DA documentation (series 000 drawings) addresses these requirements.

3.4 Creek Corridor and Buffers

While flooding in the 1% AEP event surrounds the site, the mapped alignment of the Narrabeen Creek is to the north and east of the site. On the mapped alignment of the creek a 25 m private buffer is provided to the creek. In addition to this, a minimum 25 m riparian zone offset to is present to the creek centreline. C005 provided in Appendix A of this document shows the location and extent of these zones.

3.5 Flood Modelling

Flood modelling has been undertaken to determine the impact of flooding due to the proposed development. In order to assess this, Cardno have used the Council approved Narrabeen Lagoon Flood Model.

The Narrabeen Lagoon (and tributaries) TUFLOW model, was used as a basis for the flood impact assessment. Given the size and the long run time of the model, it was truncated for the purposes of this assessment.

The truncated model was run and compared to full model prior to modification to ensure consistent output. The model extends downstream past the site by approximately 800 m (Downstream of Jackson Road) where a time varying water level boundary, derived from the catchment wide model, was established.

As the approved flood model does not have the proposed Macpherson Street Road upgrade incorporated, the first task was to update this and redefine the base case flooding for the site. In addition to this, detailed ground survey of the development site was incorporated into the model. The additional works included in the truncated base case model are as follows:

- A site survey tin provided by AT&L Associates was included in the model; and
- The design surface level of Macpherson Street upgrade (*124872 Meriton Warriewood Macpherson St DONATO Trinagular Mesh_d.dwg dated 27 September 2018)*
- Creekline levels east of the site, digitised from the works completed by the adjoining site 23-27 Warriewood Road as per the SGC Water Management Report:
  - "Proposed Aged Care Facility - 23-27 Warriewood Road, Warriewood - Water Management Report Issue 05 – dated 12 May 2017 (ref: 20160112-R01_water management report.docx)"
- Creek rehabilitation woks surface north of the site digitised from a set of PDF drawings of the Proposed Subdivision of Lot 30 & 31 located at 29-31 Warriewood Road, Warriewood NSW:
  - "Proposed Subdivision of Lot 30 & 31 – Section C D.P.5464 – 29-31 Warriewood Road, Warriewood NSW – Narrabeen Creek Rehabilitation Works dated 12 May 2016 (ref: PW5506038 Land Development Certificates - CC Plans - Civil and subdivision works (2).pdf)"

Figure 3-2 shows the updated existing site topography with the inclusion of these additional surfaces.

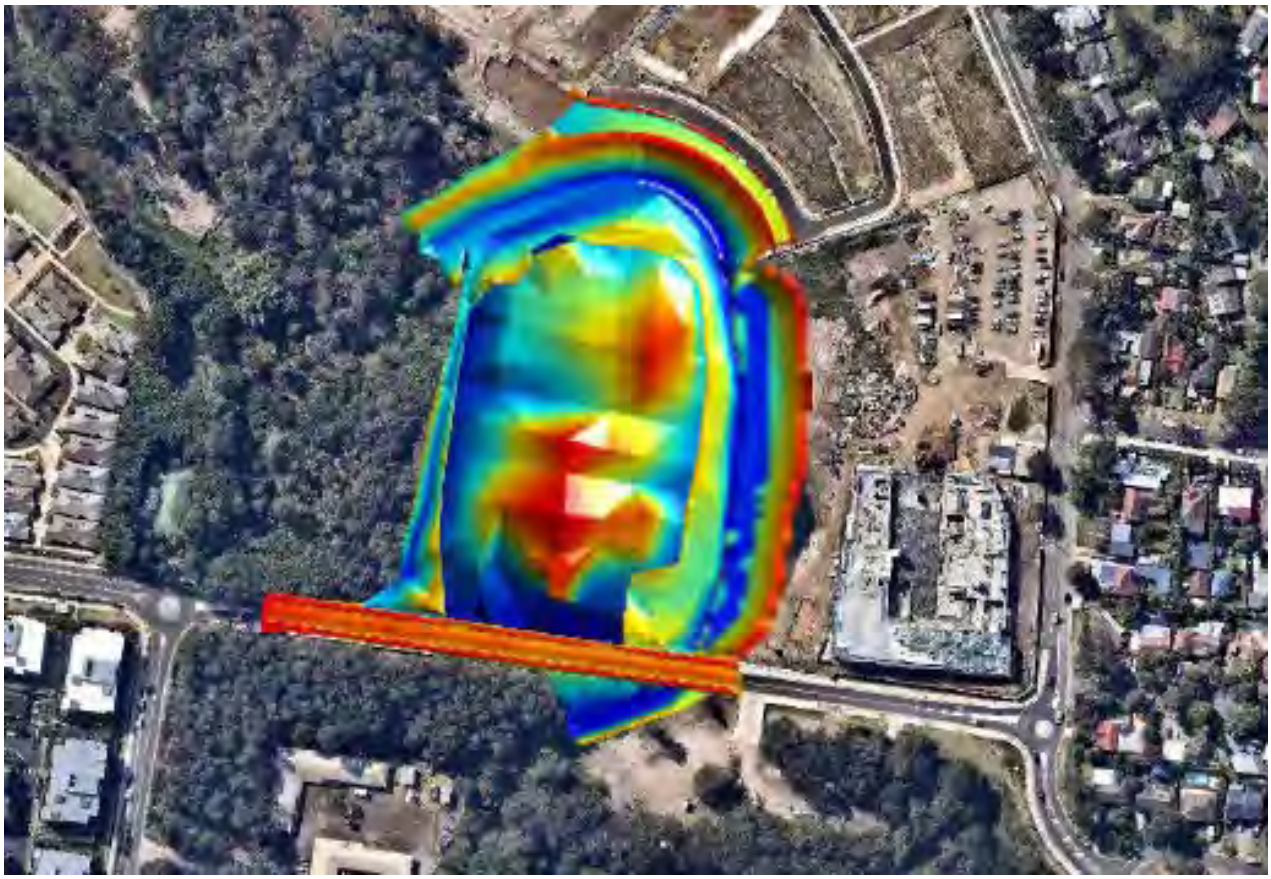


Figure 3-2 Combined Existing and Creek Works Surfaces

3.5.2 Modelling of Macpherson Street Upgrade

In order to represent the Macpherson Street upgrade the proposed alignment was incorporated into the hydraulic model. The alignment and levels utilised are on the information provided by Northern Beaches Council (Macpherson Street Warriewood Road Upgrade April 2016 reduced.pdf).

The details of the proposed culverts and bridge under Macpherson Street are provided in the Table 3-1. Initial modelling showed that due to the large size of the culverts, model instabilities occurred around the culverts causing unrealistic flood levels. To overcome this issue, the culverts were modelled in the 2D domains using the layered flow constriction approach. Appropriate flow constriction parameters were determined to represent the head loss that would occur through the culvert structure. These losses were calibrated against a HEC-RAS model of the culverts to confirm their suitability. The adopted flow constriction parameters are provided in Table 3-2.

Table 3-1 Macpherson Street Culvert and Bridge Details

Parameters	Parameters	
	Culvert	Bridge
Size	9x 3.6x1.2 RCBCs	Open Bridge with no piers in the waterway
		Base width of 3.6m
		Top width to waterway 6.9m
		Underside of Bridge 3.42 mAHD
Length	15	15
Upstream Invert Level	1.90	0.79
Downstream Invert Level	1.84	0.73

Table 3-2 Macpherson Street Culvert and Bridge Loss Details

Bridge Layer	Levels	Form Loss Coefficient (K)	Blockage (%)
Layer 1 (below deck)	Invert level of 1.9 mAHD Obvert level 3.1 mAHD	0.5	11
Layer 2 (deck level)	Underside of deck 3.1 mAHD Road Level 4.2 mAHD	1.2	100
Layer 3 (above road level)	Level to top of handrail 5.11 mAHD	0.5	10

3.5.3 Modelling of Developed Conditions

Subsequent to base case modelling and calibration, a post-development model was created to reflect the proposed development of the site. The proposed design tin of the development site was provided by AT&L Associates which was included in the flood model to assess the flood impacts. Cardno received the 12daz and 12da developed scenario design surfaces:

"181204 Revised Tins.12daz" dated 4th December 2018.

"19-12-03 - tin SUPER DESIGN.12da" dated 3rd December 2019

This 12daz and 12da file contained two design TINs of the adjacent creek corridor and finished surface level (FSL) of the site respectively.

3.5.4 Scenarios

Council's RFI requested additional scenarios and/or design flood events listed in Table 6 below.

Table 6 Design Flood Event and Requirement for Development in the Warriewood Valley

Design Event	WMS (2001), LEP or P21 DCP Requirement	Critical Duration (Peak Flood Level) from 2013 Flood Study (Catchment-Derived)	Potential Other Scenarios for Impact Assessment
50% AEP	Flow to be carried in-bank (WMS)	Unknown – likely to be of the order of 2 hours	N/A
50% AEP + CC	Requirement of P21 DCP 2014	Unknown – likely to be of the order of 2 hours	N/A
20% AEP +CC	Walkways/cycleways to be above 20% AEP (WMS) Water quality facilities to be above 20% AEP (WMS)	Unknown – likely to be of the order of 2 hours	N/A
5% AEP	Flood assessment requirements (WMS)	Unknown – likely to be of the order of 2 hours	N/A
1% AEP	Carried within public corridor (WMS)	2 hours	Low lagoon tailwater condition (lagoon at 0.6 mAHD) could be considered to identify any local effects on flow velocities that are masked by tailwater conditions and to calculate potential scouring velocities under this scenario

Design Event	WMS (2001), LEP or P21 DCP Requirement	Critical Duration (Peak Flood Level) from 2013 Flood Study (Catchment-Derived)	Potential Other Scenarios for Impact Assessment
1% AEP + CC	OSD to be above 1% AEP + Climate Change (WMS + DCP) Floor levels to be above 1% AEP + CC + freeboard (WMS and DCP) Building platforms to be at or above the flood planning level (DCP C6.1) Bridge deck obvert 0.5 m above 1%AEP (WMS)	Unknown – likely to be of the order of 2 hours	Low lagoon tailwater condition (lagoon at 0.6 mAHD) could be considered to identify any local effects on flow velocities and peak levels that are masked by tailwater conditions and to calculate potential scouring velocities under this scenario
PMF	Evacuation Planning (WMS) Flood hazards and risk to life	Unknown – likely to be of the order of 30 – 60 minutes	N/A
PMF + CC	Evacuation Planning (WMS) Flood hazards and risk to life under climate change	Unknown – likely to be of the order of 30 – 60 minutes	N/A

To address the above, the revised flood assessment considered both open and closed entrance conditions, with sea level rise (SLR) and climate change (CC). The scenarios are summarised in Table 3-3.

It is considered the intent of the low tailwater scenario specified by Council is to ensure the site does not result in increased velocities through sensitive areas downstream of the site, while also ensuring the development is not detrimental to the current channel. As such a static low tailwater (0.6 mAHD or 1.5 mAHD in CC considerations) has been applied, which is considered conservative for this analysis.

The PMF with a climate change tailwater scenario has not been established within the Council provided model and thus cannot be quantified.

Additional modelling for the 50% and 20% AEP (E20 and D15) was also undertaken to simulate the flood conveyance capacity in the more regularly occurring events. The events were implemented using constant inflows extracted from the SGC Water Management Report for 23-27 Warriewood Road:

> *"Proposed Aged Care Facility - 23-27 Warriewood Road, Warriewood – Water Management Report Issue 05 – dated 12 May 2017 (20160112-R01_water management report.docx)"*

These additional model scenarios have been tabulated in Table 3-3.

Table 3-3 Summary of TUFLOW Model Scenarios

TUFLOW	Scenario	Description	Tailwater Condition	Design Events	Requirements
E21_CC	Base Case	Closed entrance with 0.9m SLR & 30% CC	Dynamic	1% AEP event with 9hr and 12hr storms	
E21_DES	Base Case	Open entrance with tailwater @ 0.6mAHD & no CC	Static	1% AEP event with a 2 hr storm PMF event	
E21a_CC	Base Case	Open entrance with tailwater @ 0.6mAHD + 0.9m SLR & 30% CC	Static	1% AEP event with a 2 hr storm	
E20	Base Case	Closed entrance with 0.9m SLR	Static	50% & 20% AEP event with a constant flow	
DE16_CC	Developed Case	Closed entrance with 0.9m SLR & 30% CC	Dynamic	1% AEP event with 9hr and 12hr & 20% AEP with 2hr, 6hr and 9hr storms	WMS- 1% AEP with respect to OSD and building floor level freeboard. 20% AEP for walkways, cycle ways and water quality devices
DE16_DES	Developed Case	Open entrance with tailwater @ 0.6mAHD & no CC	Static	1% AEP event with a 2 hr storm	Alternate scenario for local velocity(scour) impact
DE16a_CC	Developed Case	Open entrance with tailwater @ 0.6mAHD + 0.9m SLR & 30% CC	Static	1% AEP event with a 2 hr storm	Alternate scenario for local velocity(scour) and peak flood level
DE16b_DES	Developed Case	Closed entrance with no SLR & no CC	Dynamic	1% and 5% AEP events with the 2hr storm	1% AEP conveyance within public corridor, and 5% flood assessment WMS
DE17	Developed Case	Closed entrance with 0.9m SLR	Static	50% & 20% AEP event with a constant flow	

4 Flood Modelling Results

4.1 Impacts of the Roadway Upgrade

A comparison of the base model vs the model with the proposed Macpherson Street upgrade was undertaken to confirm the impact of the alignment. In general, no actionable impacts were noted. Table 4-1 provides the 1% AEP with 30% climate change flood level reporting the impact of the road upgrade to the modelling results.

Table 4-1 Base Case Model Validation Results

Reporting Location	1% AEP with 30% climate change Flood Levels (mAHD)	
	Model without Road Upgrade	Model with Road Upgrade
Upstream of Macpherson Street, West of Development	3.78	3.80
Upstream of Macpherson Street, East of Development	3.78	3.78
Immediately Downstream of Macpherson Street	3.77	3.77

4.2 Developed Flood Mapping

Figures 4-1 to Figure 4-5 show the maximum flood depth plots for the various scenarios when the development is considered onsite.

4.2.1 1% AEP + CC (Closed Outlet)

Figure 4-1 shows the depth extent of the 1% AEP + CC for the site. This design scenario has been utilised to confirm design levels for the site and for impact analysis.

4.2.2 20% AEP + CC (Closed Outlet)

Figure 4-2 shows the depth extent of the 20% AEP + CC for the site. In accordance with the WMS, walk ways, cycle ways and water quality devices are to be above this level. The proposed water quality devices are confirmed to be above this level.

4.2.3 1% AEP (Closed Outlet)

Figure 4-3 shows the depth extent of the 1% AEP for the site. This design scenario has been utilised to confirm the 1% AEP sits within the public corridor. Based on the design the full flow path to the north of the site does not encroach into the private buffer. In general, the 1% AEP flood extent is generally contained within the public corridor.

4.2.4 5% AEP (Closed Outlet)

Figure 4-4 shows the depth extent of the 5% AEP for the site. This design scenario has been utilised to confirm that stormwater water quality treatment systems can be located above the 5% AEP design flood event.

4.2.5 1% AEP + CC (Open Outlet)

Figure 4-5 shows the depth extent of the 1% AEP + CC for the site with a low tailwater level. This scenario has been utilised to determine if the development of the site results in changes to the velocity profile within and surrounding the site.

4.2.6 1% AEP (Open Outlet)

Figure 4-6 shows the depth extent of the 1% AEP for the site with a low tailwater level. Similar to the above, this scenario has been utilised to determine if the development of the site results in changes to the velocity profile within and surrounding the site.

4.2.7 Hazard Assessment

Figure 4-7 shows the hazard profile for the site in the 1% AEP with 30% climate change plus 0.9 m sea level rise. In events that exceed the roadway level however, it is recommended that residents onsite do not evacuate. Further discussion on emergency management procedures is provided in Section 5.

Figure 4-8 shows the maximum depth experienced onsite during the PMF event. The PMF does not exceed the proposed finished floor level of the site however temporary isolation of the site of approximately 4 hours may occur in this event due to inundation of Macpherson Street. To address this, a flood emergency management response has been prepared. The Warriewood FEMP (Cardno 2018a) provides this assessment.

The PMF Event is largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation coupled with the worst flood producing catchment conditions. The PMF event is generally considered to have a probability of occurrence between 1:10,000 and 1:100,000.

4.2.8 Flood Impacts

Figure 4-9 shows the water level impact map the PMF event when the development is considered onsite, comparing the developed condition to the base condition model with the Macpherson Street Road upgrade incorporated. No impacts in excess of 20 mm are recorded.

Figure 4-10 shows the water level impact map of 1% AEP with 30% climate change plus 0.9m sea level rise. No impacts in excess of 20 mm are recorded.

4.2.9 Velocity Impact

Figure 4-10 and Figure 4-11 show the velocity impact of the 1% AEP and 1% AEP + CC with the open entrance conditions. These figures show that the development will not result in any significant increase in the peak velocity with up to +0.7 m/s increase in-bank velocities onsite than the existing condition. No increase downstream of the site under the proposed design is noted. Minor variances outside the site are noted however these are primarily attributed to minor model noise, which explains the scattered nature of the changes shown.

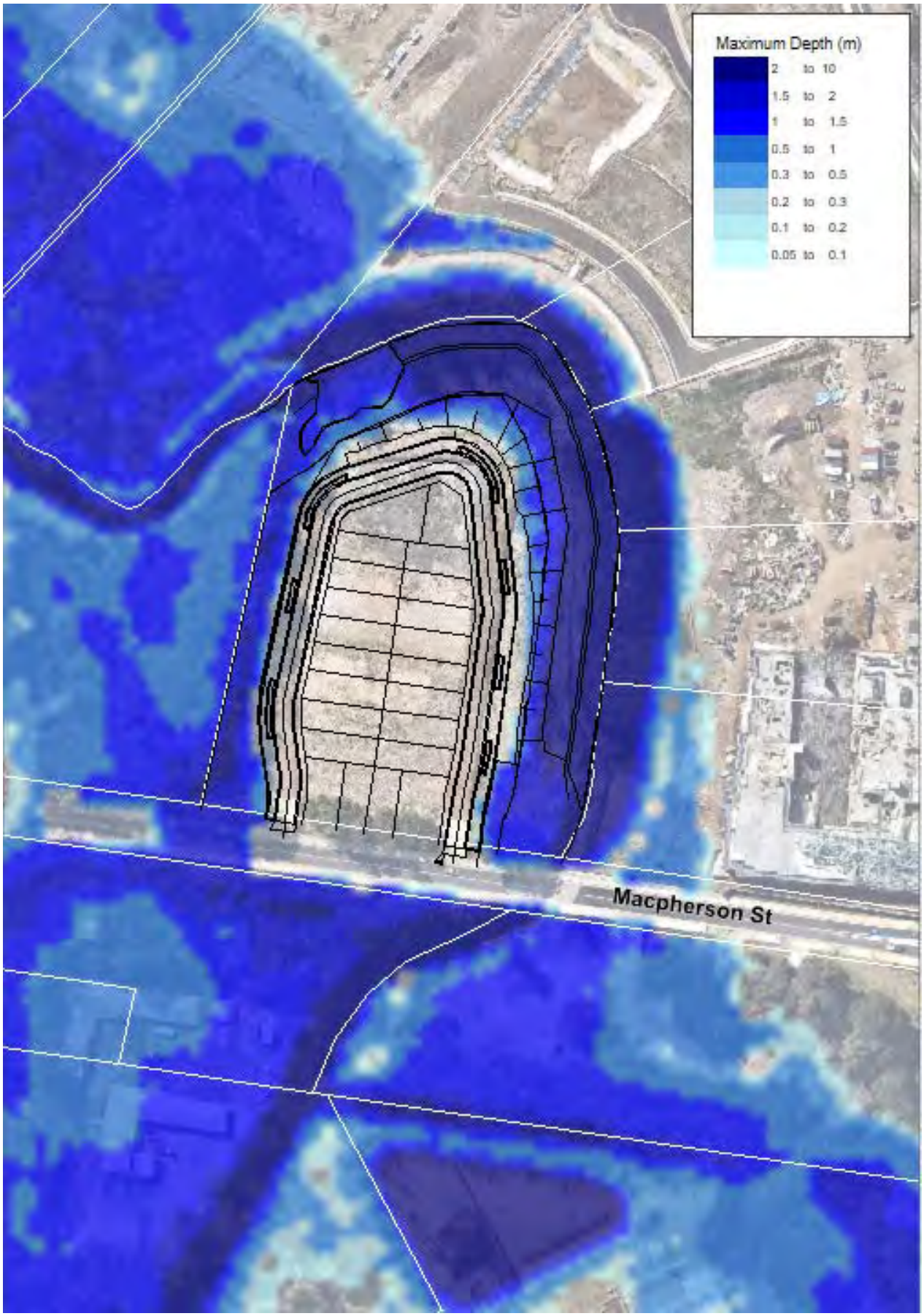


Figure 4-1 1% AEP Event Maximum Depth (DE16_CC)

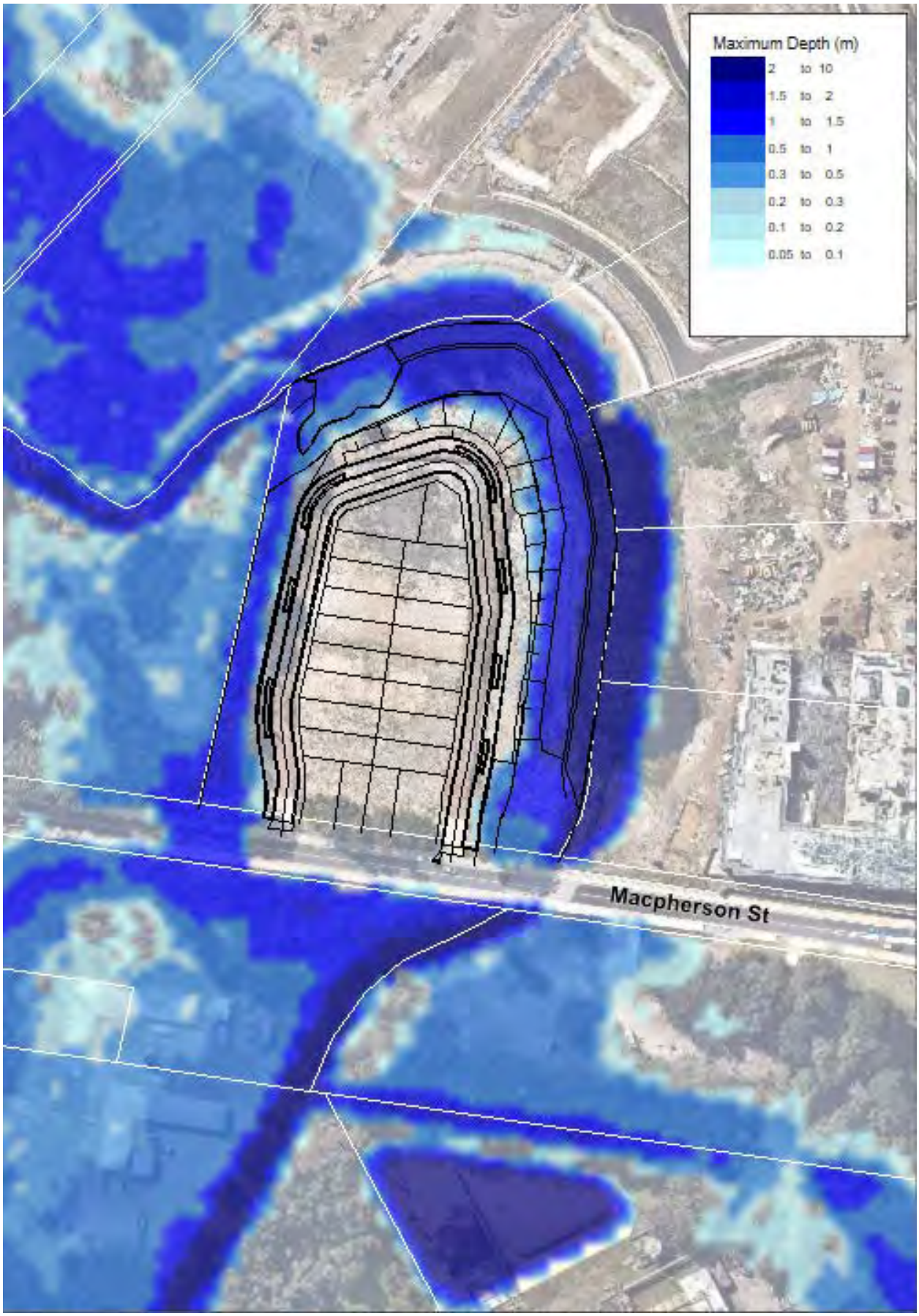


Figure 4-2 20% AEP Event Maximum Depth (DE16_CC)

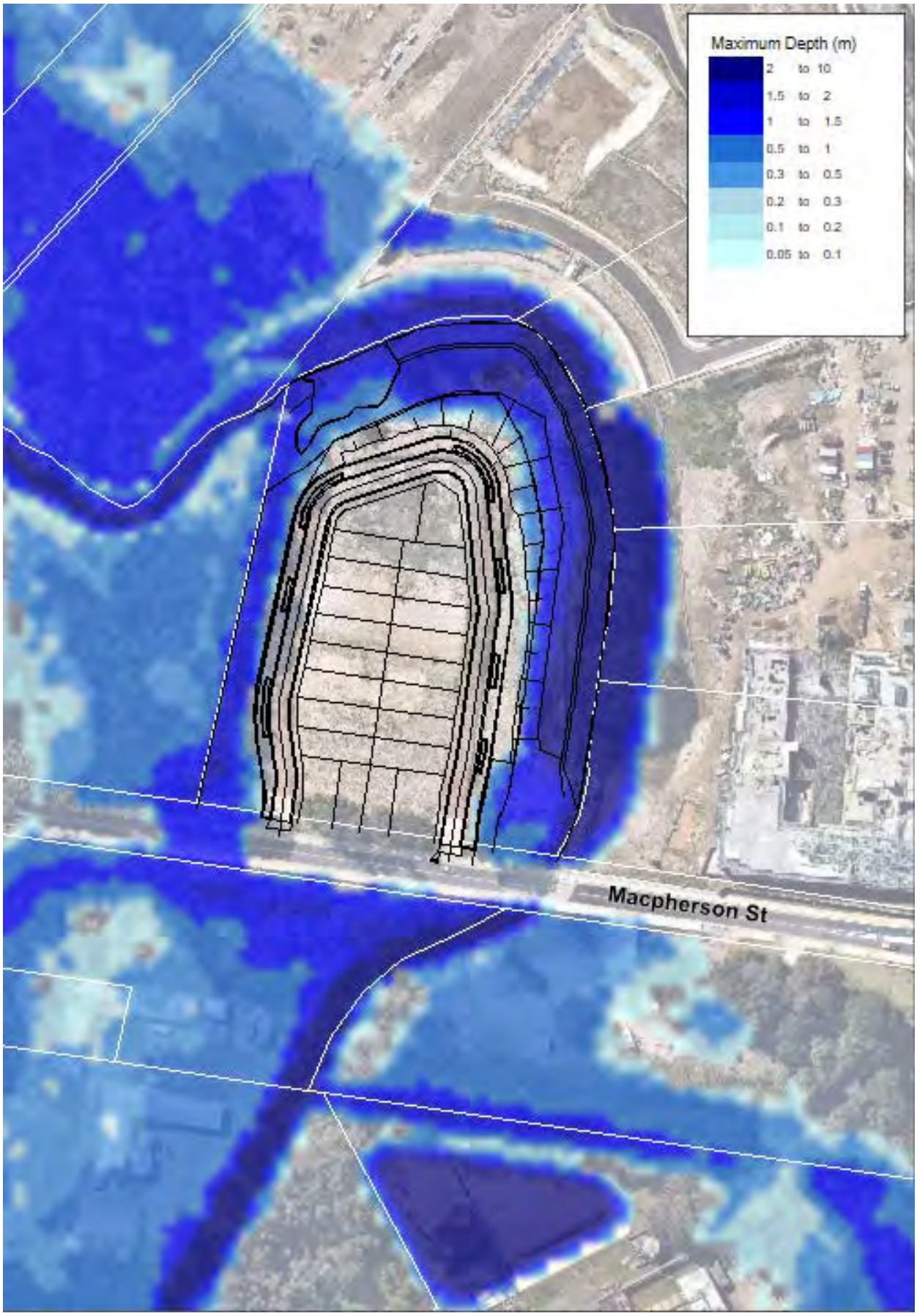


Figure 4-3 1% AEP Event Maximum Depth (DE16b_DES)

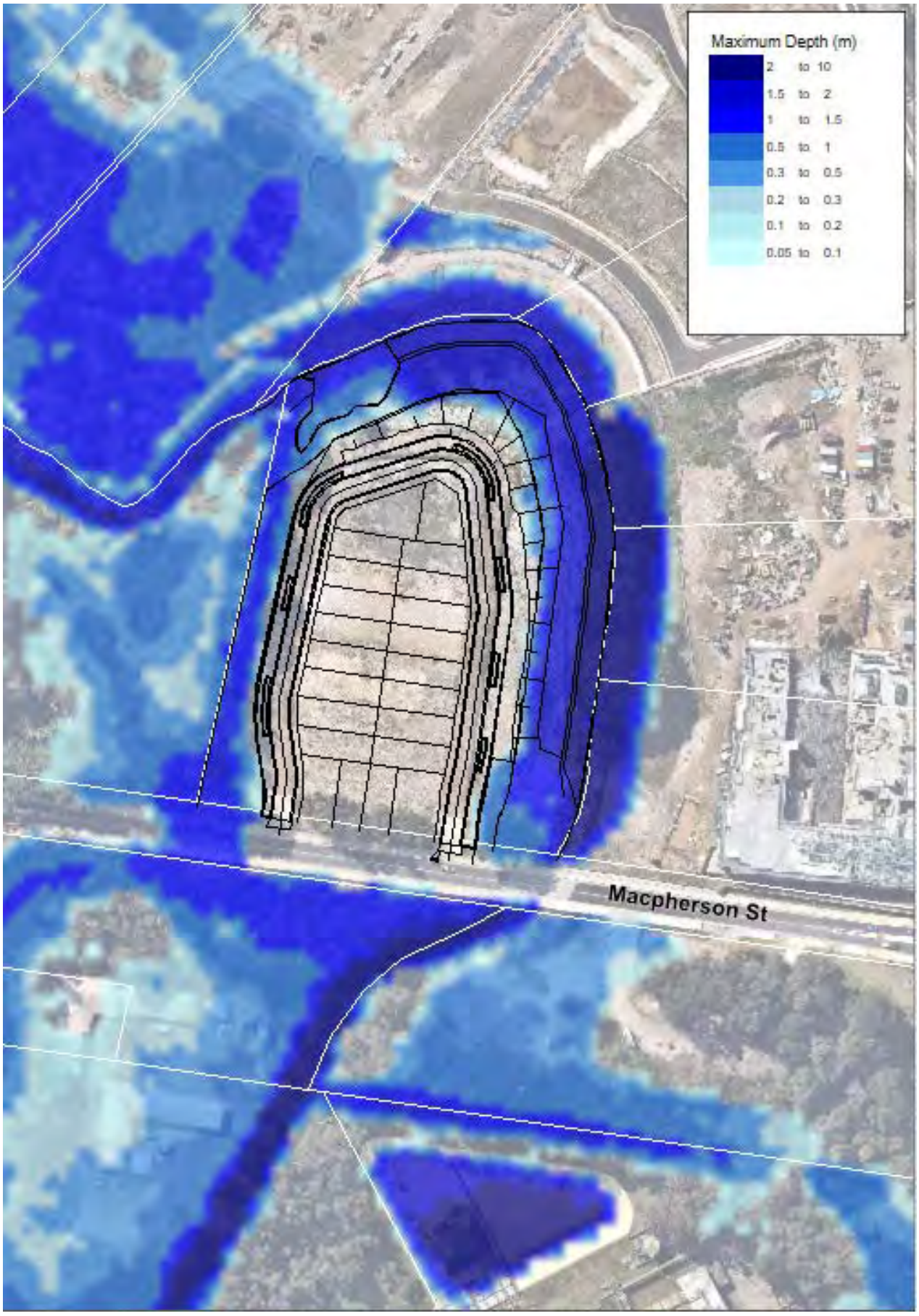


Figure 4-4 5% AEP Event Maximum Depth (DE16b_DES)

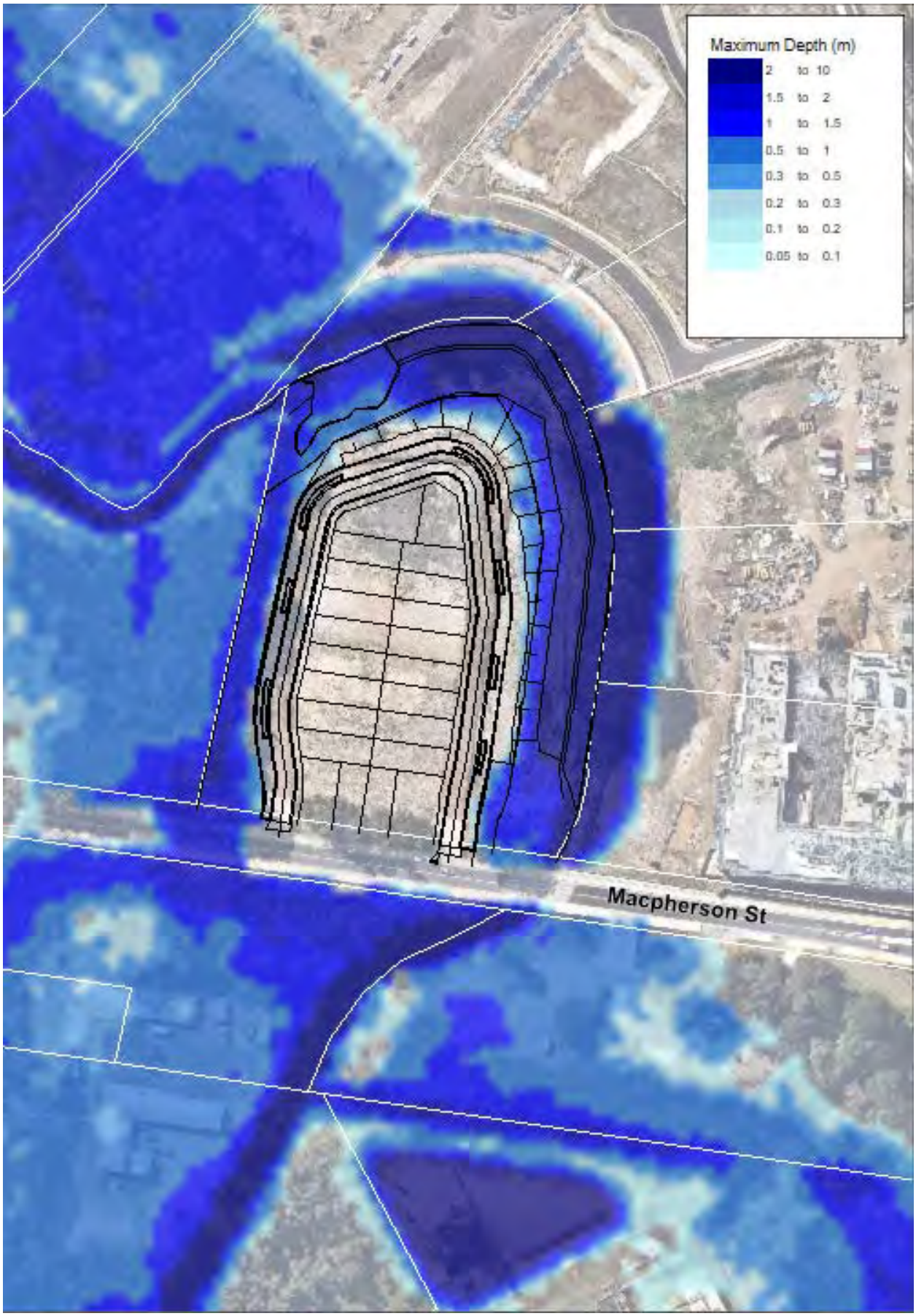


Figure 4-5 1% AEP Event Maximum Depth (DE16a_CC)

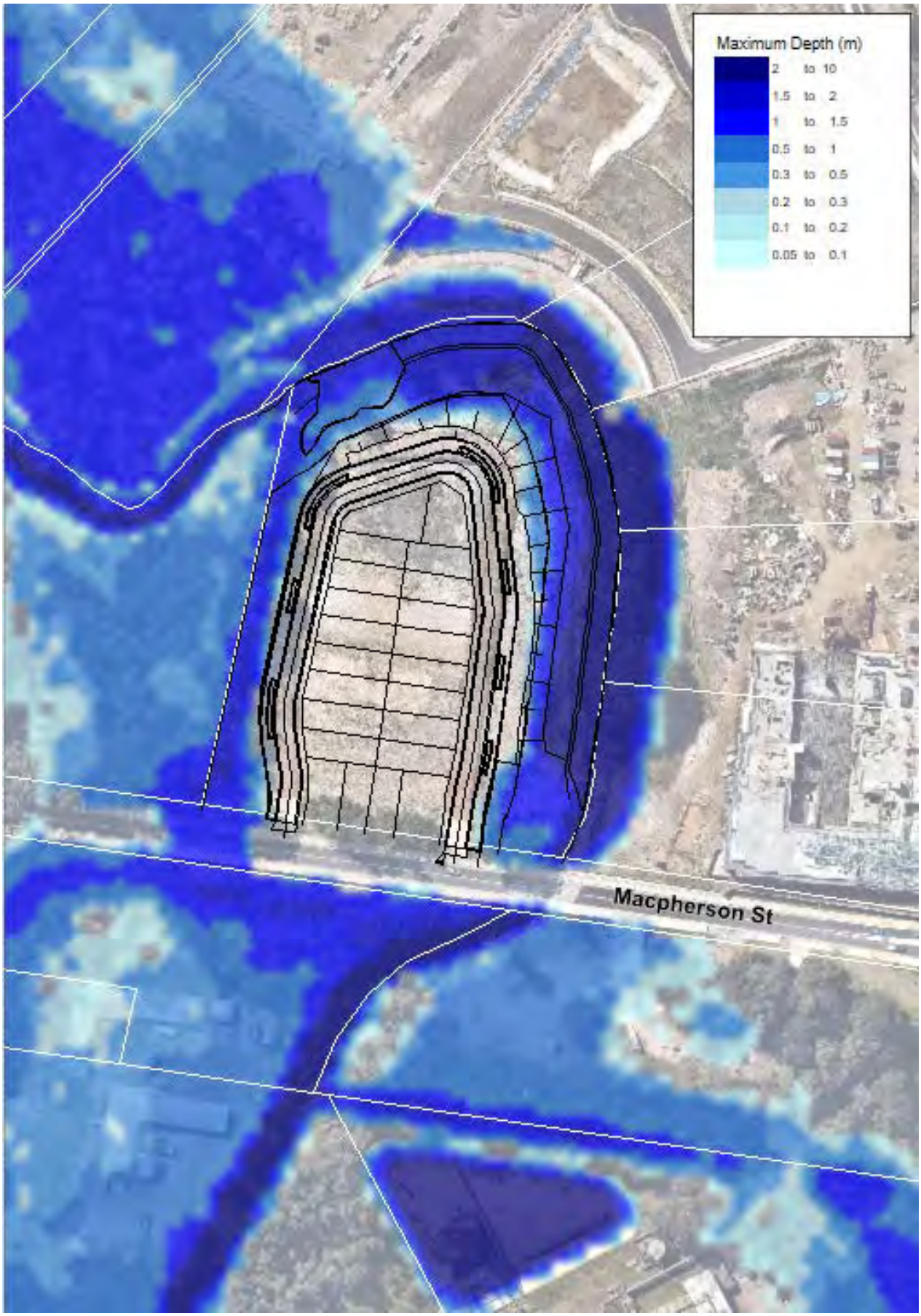


Figure 4-6 1% AEP Event Maximum Depth (DE16_DES)

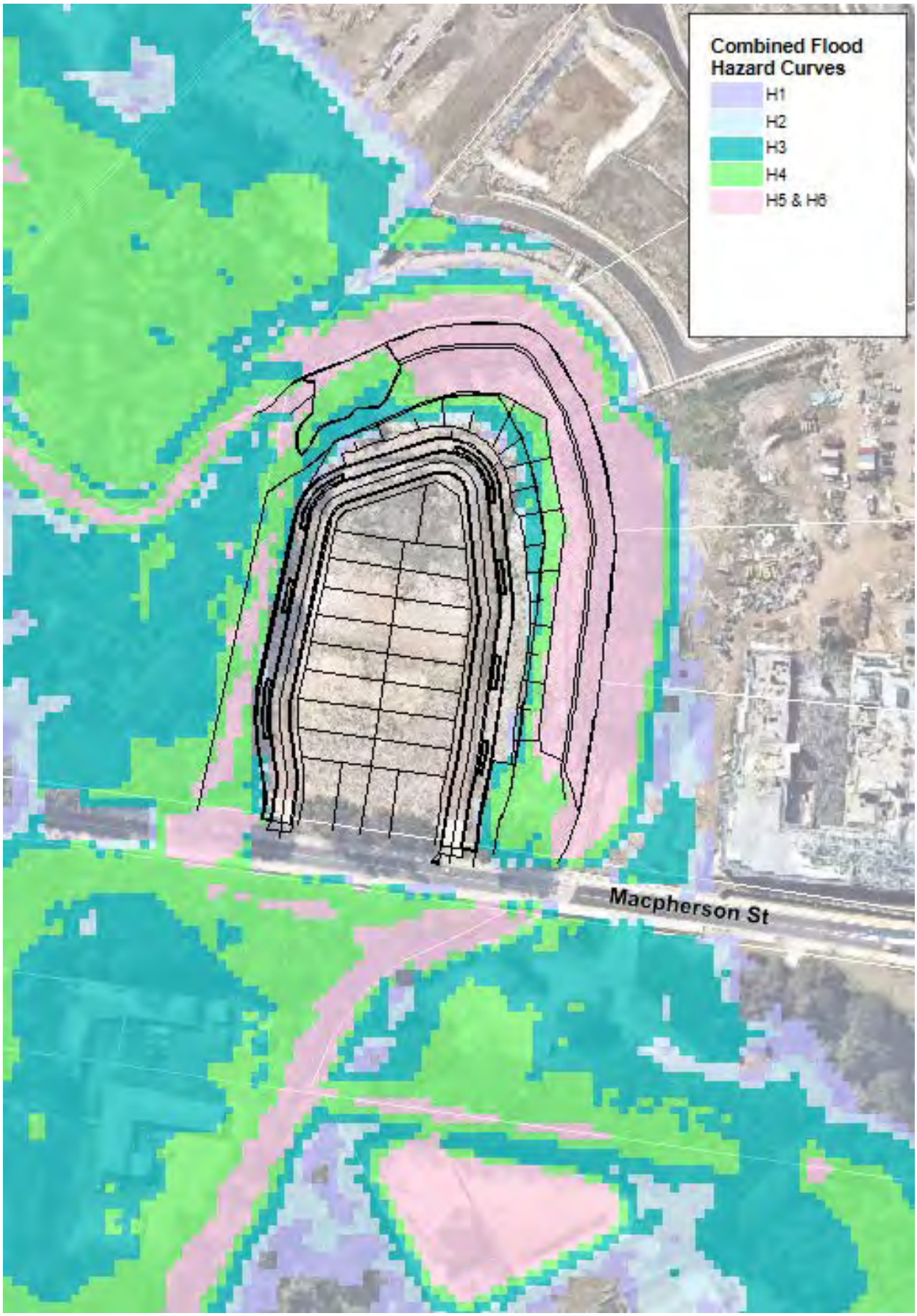


Figure 4-7 1% AEP Event Maximum Hazard (DE16_CC)

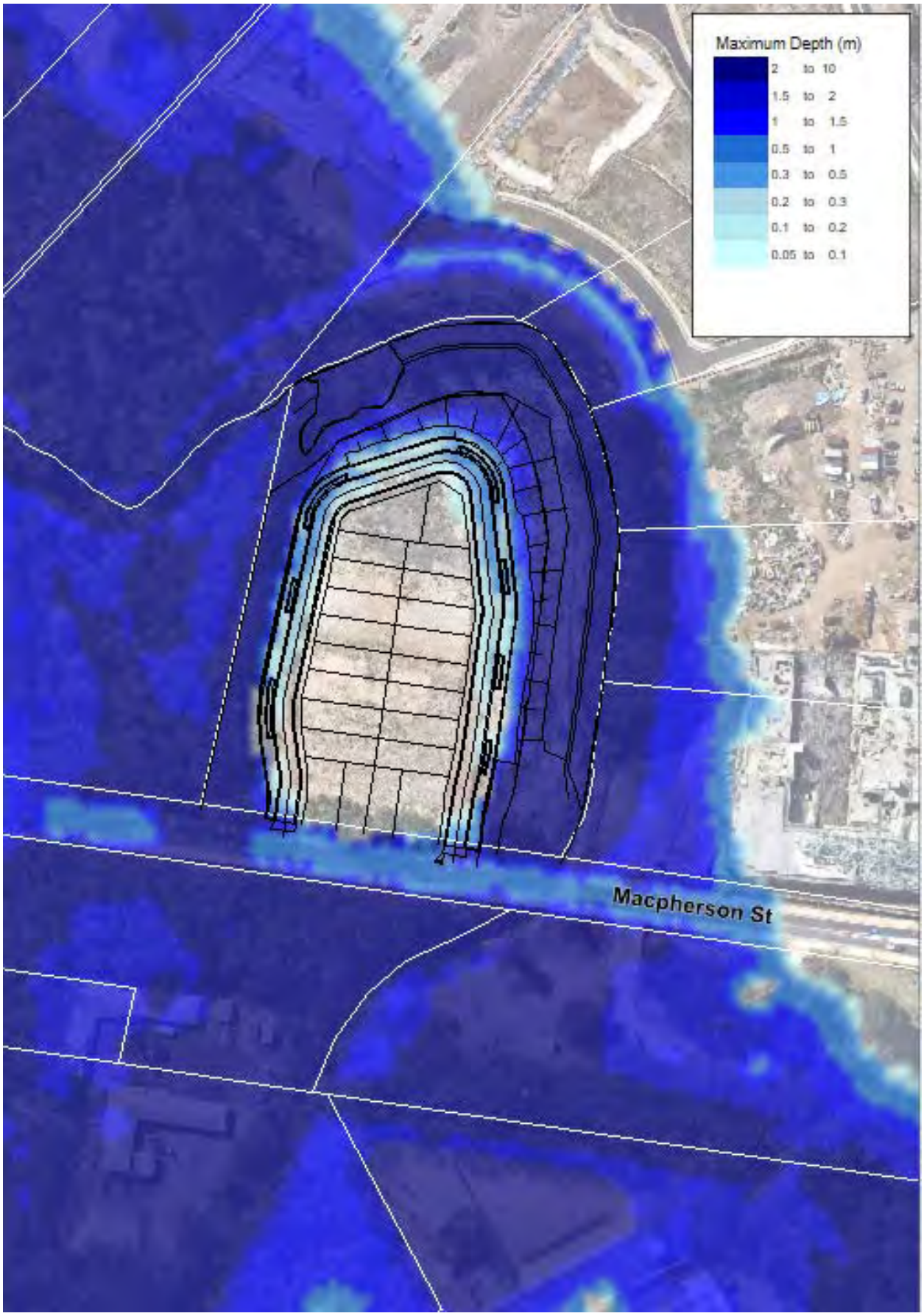


Figure 4-8 PMF Maximum Depth (DE16_DES)

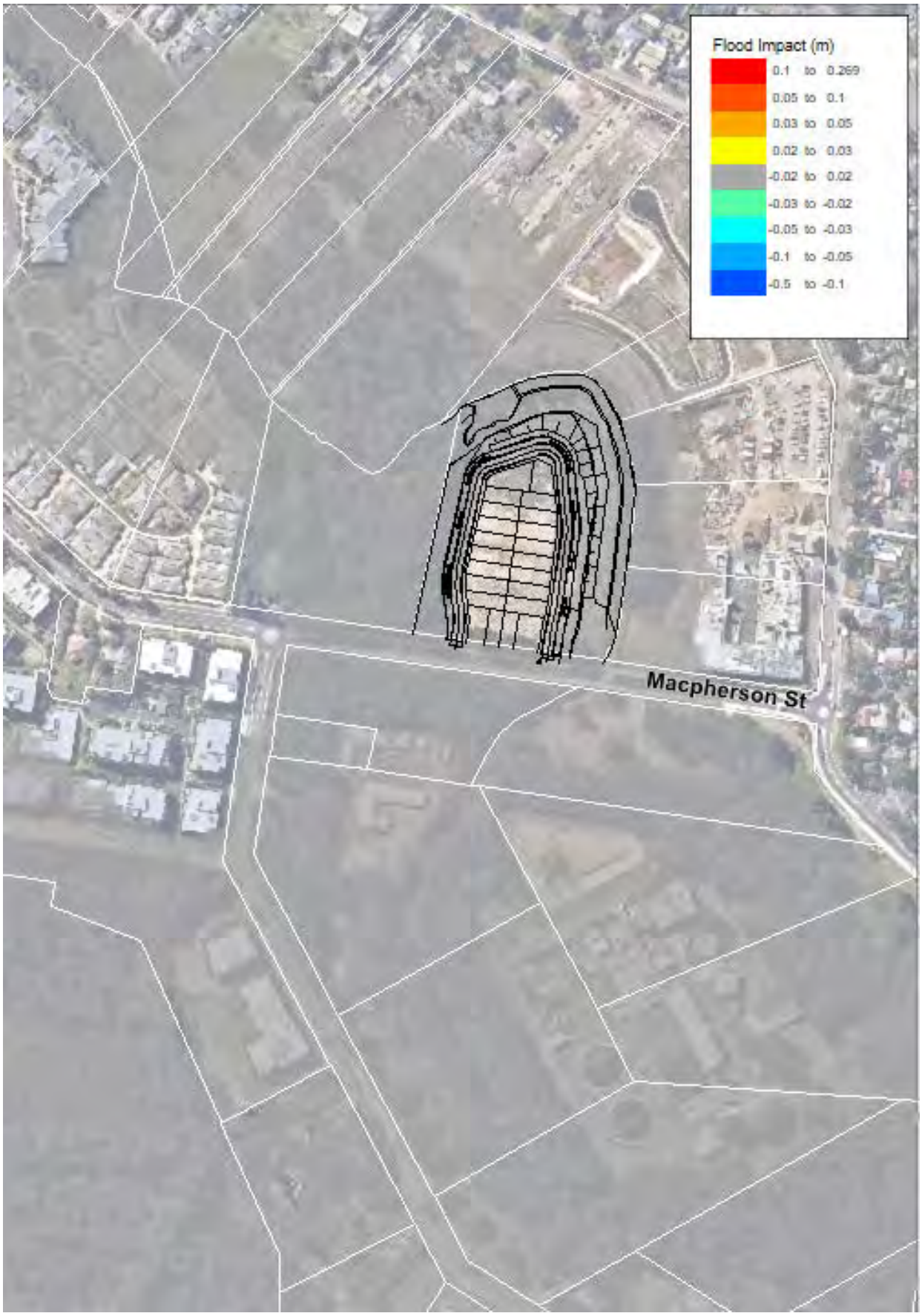


Figure 4-9 PMF Flood Level Impact (DE16_DES – E21_DES)

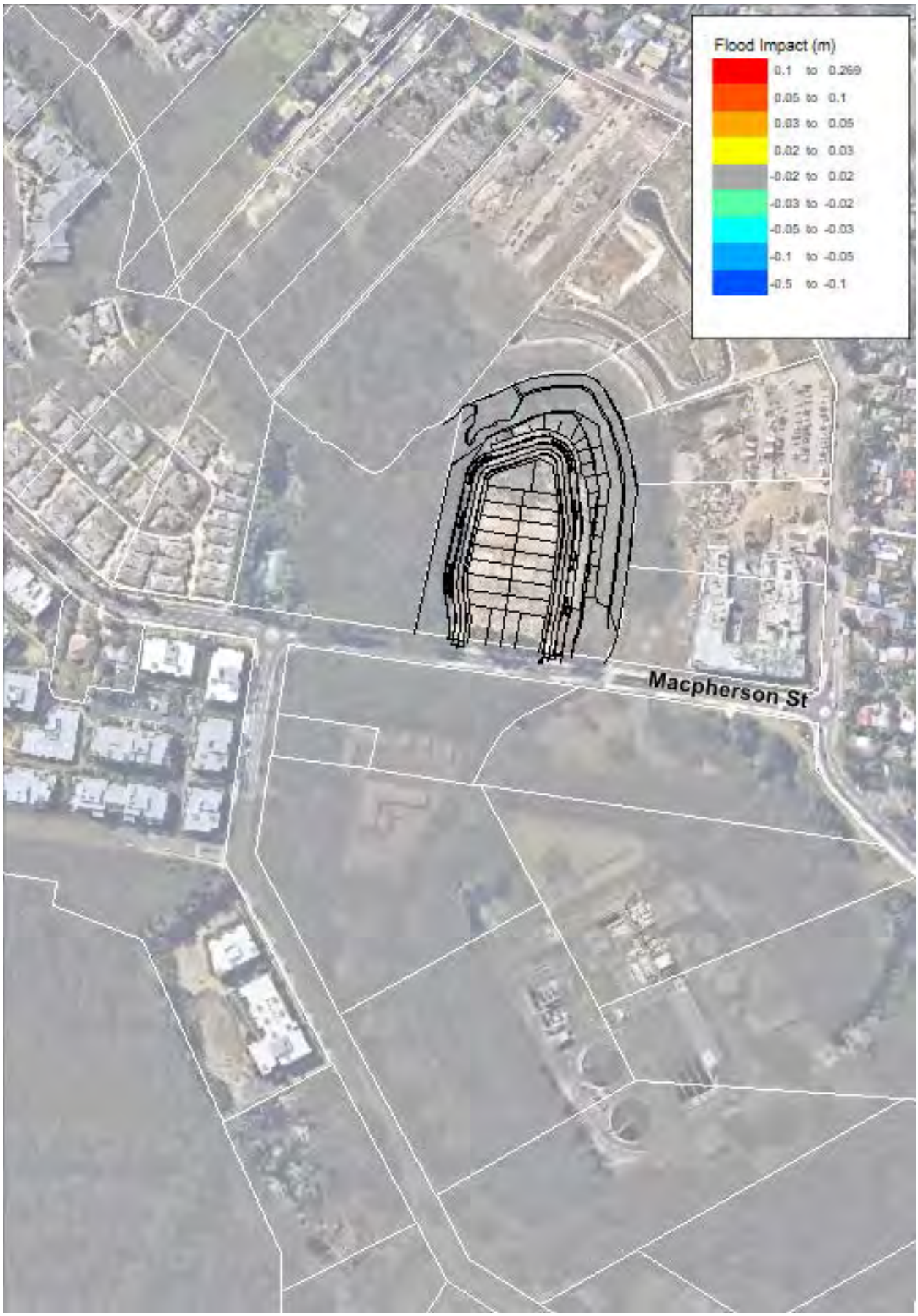


Figure 4-10 1% AEP Event Flood Level Impact (DE16_CC – E21_CC)

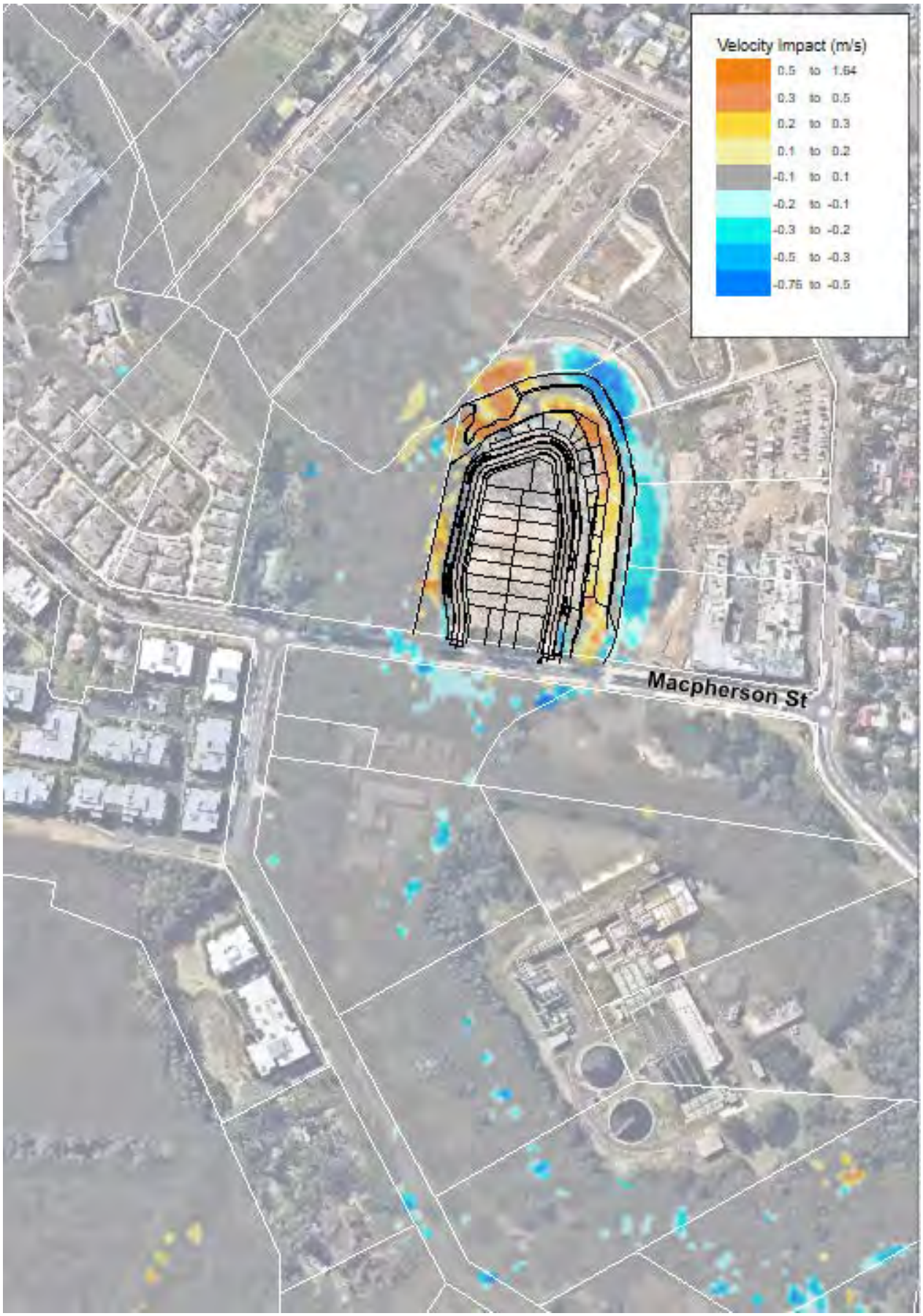


Figure 4-11 1% AEP Event Velocity Change (DE16_DES – E21_DES)

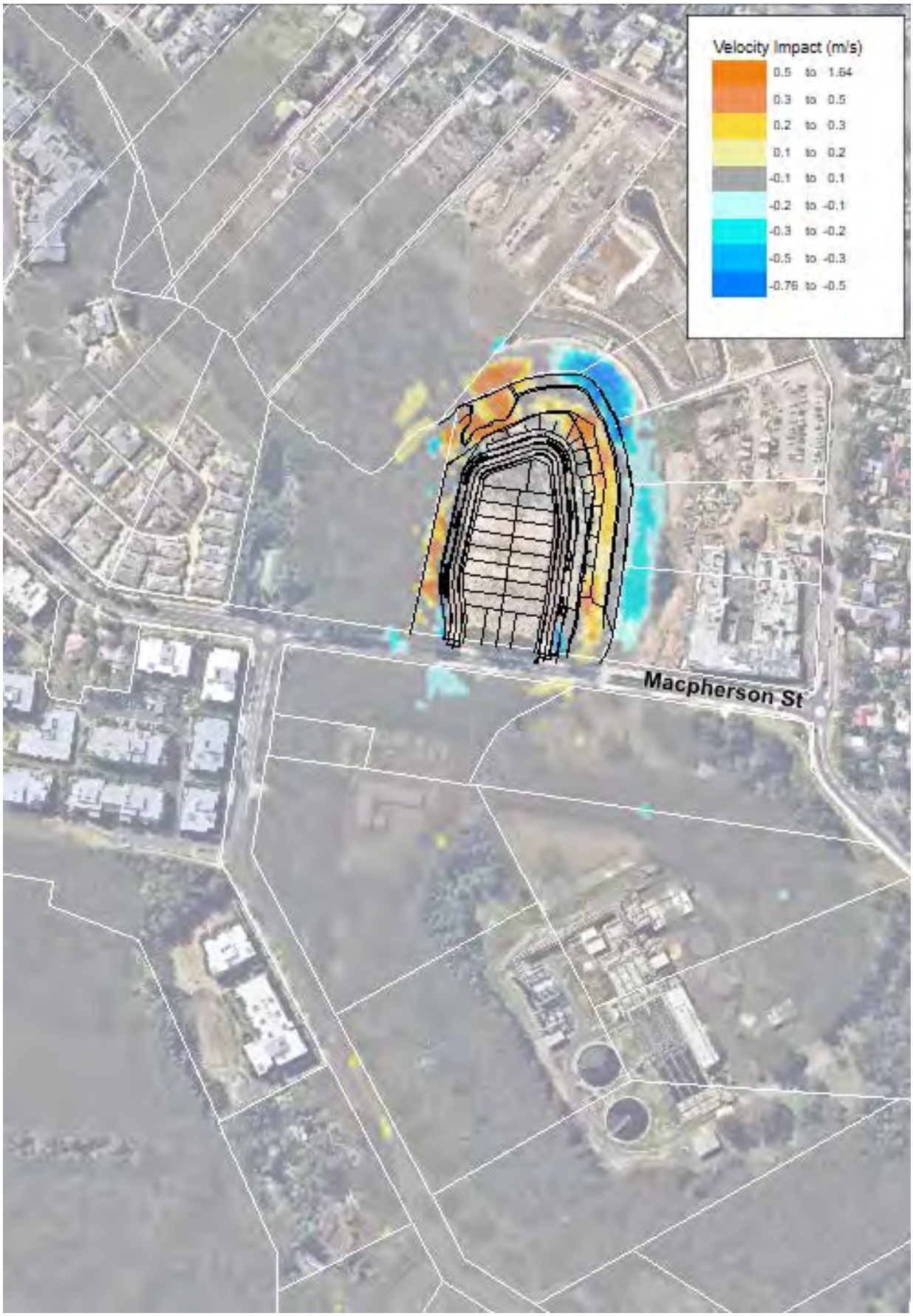


Figure 4-12 1% AEP Event Velocity Change (DE16a_CC – E21a_CC)

4.3 Frequent Flood Events

The GHD review (GHD, 2017), provided in Appendix B, noted that to date the hydraulic analysis undertaken has not considered events lower than the 1% AEP 30% CC plus 0.9 m.

The hydraulic model has been updated to simulate the flood conveyance capacity in the more regularly occurring events (20% and 50% AEP 20% CC plus 0.9 m) implementing constant inflows extracted from the SGC Water Management Report for 23-27 Warriewood Road as stated in Section 3.5.4. This assessment of the event has been undertaken to confirm that no impacts are presented onsite during this event. Figure 4-13 and Figure 4-14 confirms no adverse impact.

Minor water level reductions are noted upstream of the site in the 20% AEP these reductions are less than 50 mm and when considered against the magnitude of the event are deemed to be of little environmental consequence. In the 50% AEP no reductions greater than 20 mm are predicted upstream of the site.

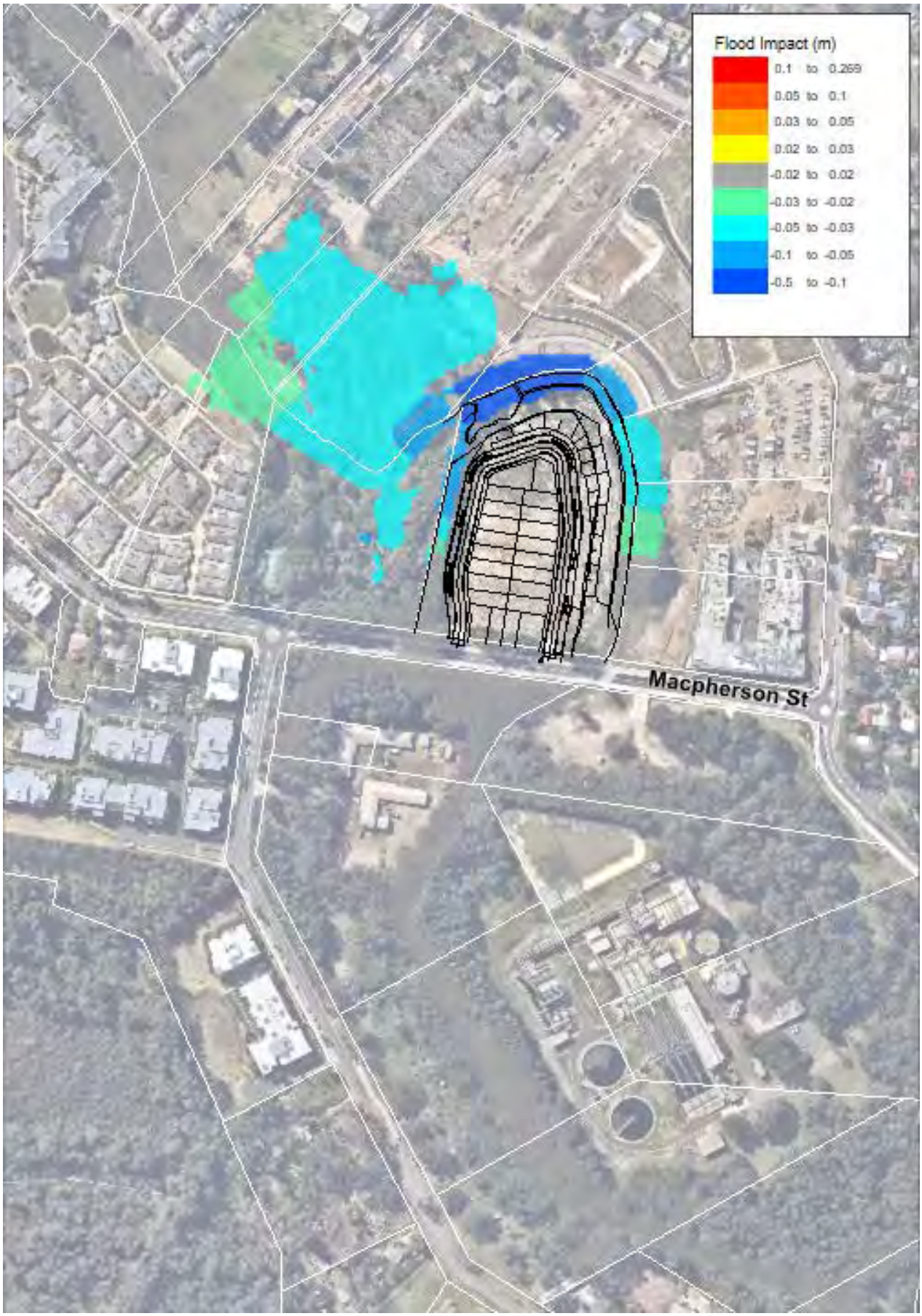


Figure 4-13 20% AEP Event Flood Level Impact (DE17 – E20)

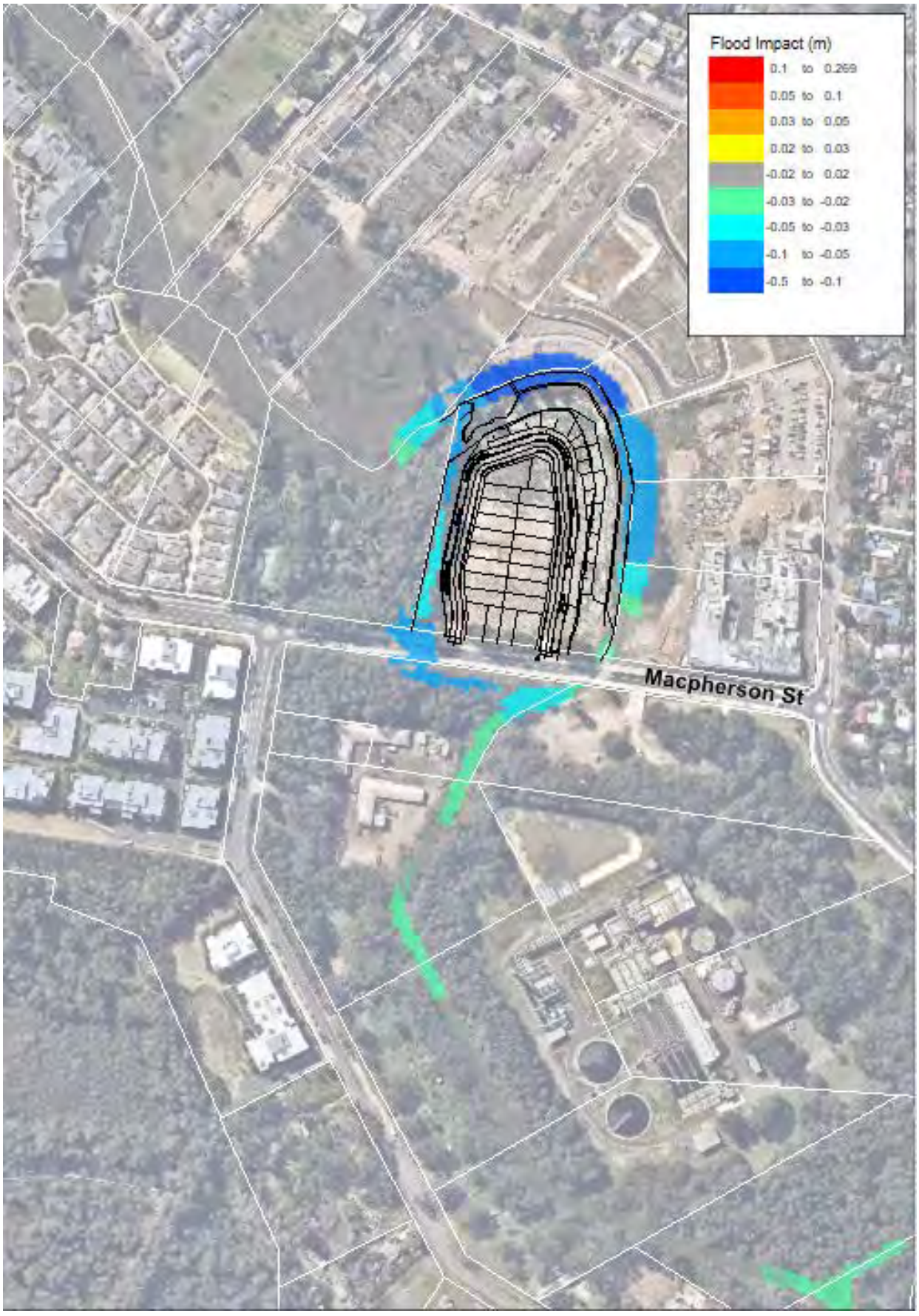


Figure 4-14 50% AEP Event Flood Level Impact (DE17 – E20)

4.4 Flood Storage

Table 4-2 lists the flood storage volume of the development for the pre and post development scenarios.

Table 4-2 Flood Storage Calculations

Scenario	1% AEP with climate change Volume (m^3)	Net Loss (-) or Gain (+) Volume (m^3)
Pre-development	18,245	n/a
Post-development without excavation	18,100	-145

This assessment demonstrates only a minor physical loss (-145 m^3) of flood storage occurs onsite in events up to the 1% AEP with climate change due to biodiversity constraints and civil controls of the site. Even though there is a loss in the flood storage, this equates to less than 1% of flood storage onsite and results in no adverse impacts to the floodplain and the safety of the residents on the development.

5 Flood Emergency Management Planning

The proposed residential properties onsite are flood immune up to the 1% AEP climate change and sea level rise (0.9m) and in the PMF event. Figure 4-8 shows the PMF depth extent for the site. Cardno has issued a *Flood and Emergency Management Plan dated 19 December 2018,* provided in Appendix C. This has been developed to identify and mitigate the risk of flooding onsite.

The proposed development has a prescribed finished floor level of 4.9 mAHD that will ensure flood immunity up to and including extremely unlikely event (PMF). A flood emergency management plan (Cardno, 2017a) has been prepared to identify the residual risk onsite and provide solutions which minimise the risk to life to residents has been developed.

The following outcomes are identified within the FEMP (Cardno 2018) provided in Appendix C:

- The defined FPL is in excess of the predicted flood levels of the 0.1% AEP event under existing catchment conditions
- There is insufficient warning time to enable safe evacuation thus Shelter-In-Place is required;
- Dwellings are required to enable vertical Shelter-In-Place, noting that in a PMF event the bottom flood will not be inundated;
- Dwellings will not be required to be specially engineered to enable Shelter-In-Place; and
- The time of inundation of the site is relatively short with the maximum expected time of inundation of the surrounding roadway in the order of 4.0 hours. The depth of inundation across Macpherson Street in the PMF event reaches a maximum of 600 mm

6 Conclusions

In order to determine and manage the flood impacts associated with the proposed development of 2 Macpherson Street, Warriewood a flood impact assessment for the site has been prepared. Hydraulic modelling of the site has been undertaken to determine the potential impacts of the development within the floodplain and to ensure that the impacts and risks posed by the development of the site are understood.

Based on the analysis undertaken the following outcomes have been established:

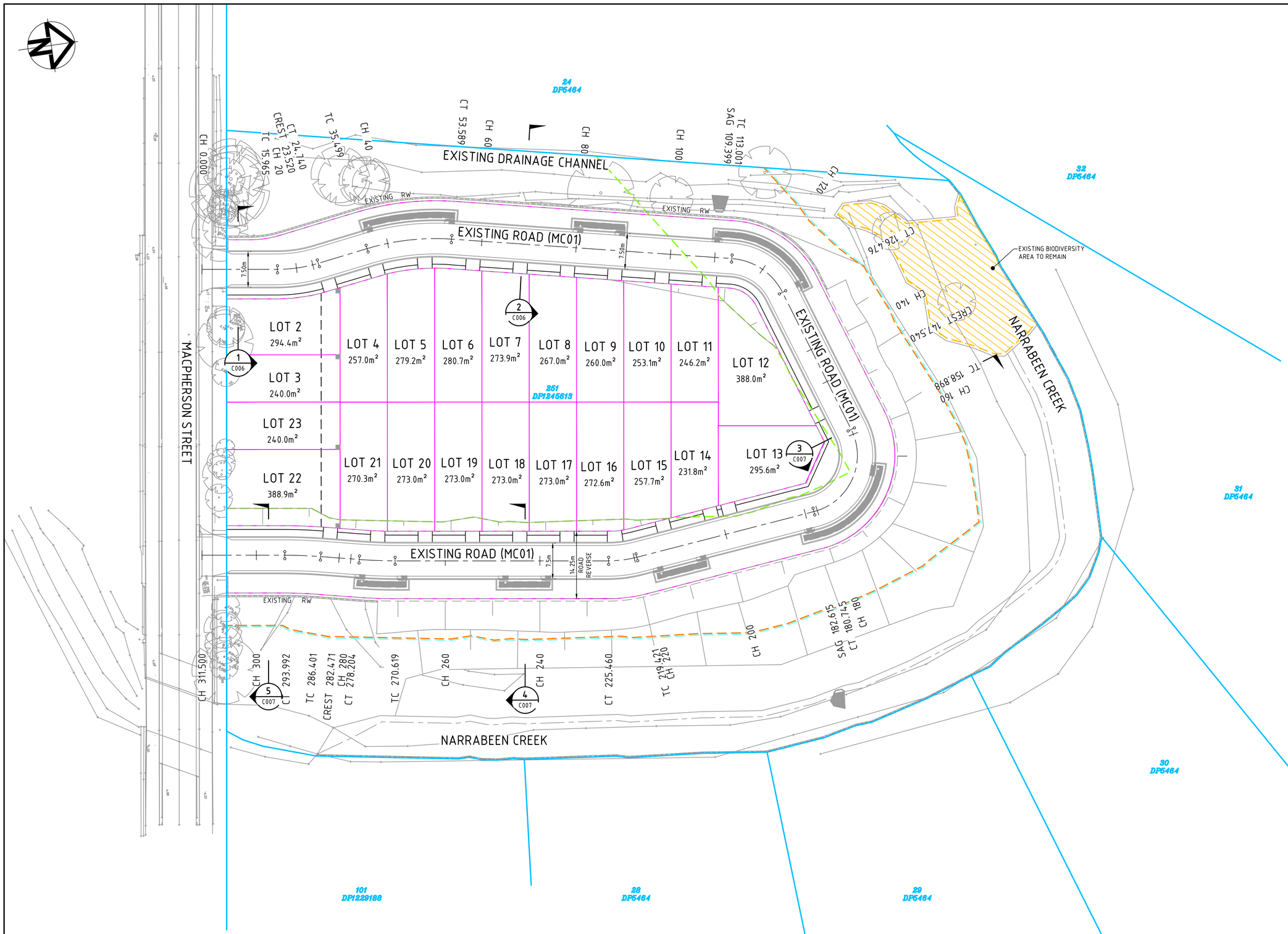
- The final fill level of dwellings onsite is 4.9 mAHD, which is above the defined flood planning level for the site (1% AEP climate change and sea level rise (0.9m);
- Up to and including the extreme events, no adverse flood impacts in excess of 20 mm occur upstream and downstream of the site.
- There is only a minor physical loss (<-145 m^3) of flood storage occurs onsite in events up to the 1% AEP with climate change. This loss does not result in any impacts external and internal of the site and is therefore deemed acceptable.
- Shelter-in-Place is a viable emergency response option and does not result in an increase in risk to life if appropriately incorporated into the development.

Overall the proposed development demonstrates compliance against Council's flooding conditions.

0B2
Macpherson
Street,
Warriewood

APPENDIX
A

DRAWING C005



GENERAL ARRANGEMENT LEGEND

EXISTING

- EXISTING BOUNDARY
- 3.0 — EXISTING CONTOUR
- EXISTING 20m ASSET PROTECTION ZONE
- EXISTING TREE
- EXISTING CREEK CENTERLINE
- EXISTING 25m RIPARIAN CORRIDOR
- EXISTING 25m PRIVATE BUFFER

WORKS INSTALLED AS PART OF DA N03981

- EXISTING BIODIVERSITY EXTENTS
- K&G — EXISTING KERB & GUTTER
- RK — EXISTING ROLL TOP KERB AND GUTTER
- EXISTING BATTER
- RRW — EXISTING ROCK RETAINING WALL
- RW — EXISTING RETAINING WALL
- 375ø — EXISTING STORMWATER PIPE (SHOWING SIZE)
- EXISTING STORMWATER KERB INLET PIT
- EXISTING STORMWATER SURFACE INLET PIT
- EXISTING STORMWATER RAINGARDEN
- A\1 — EXISTING STORMWATER PIT NUMBER

PROPOSED

- PROPOSED BOUNDARY
- PROPOSED EASEMENT
- PROPOSED DRIVEWAY. LOCATIONS SHOWN ARE INDICATIVE ONLY AND ARE SUBJECT TO FUTURE APPROVAL

NOTES

1. ROADWORKS, EARTHWORKS, STORMWATER AND CREEK WORKS N03981 TO FORM PART OF THE EARLY WORKS PACKAGE. REFER TO THE EARLY WORKS PACKAGE FOR DETAILS.
2. REFER DRAWING C020 FOR CIVIL DETAILS.

Issue	Description	Date
C	ISSUED FOR APPROVAL	22-07-19
B	ISSUED FOR APPROVAL	17-07-19
A	ISSUED FOR APPROVAL	12-07-19

100mm on Original

Bar Scales

0 10 20 30 40m

1 : 400 @ A1 1 : 800 @ A3

Client

KARIMBLA
CONSTRUCTION SERVICES (NSW)
PTY LIMITED

Level 11, 528 Kent Street, Sydney NSW 2000
Tel: (02) 9287 2888 Fax: (02) 9287 2777
Email: info@design.meriton.com.au
Internet: http://www.meriton.com.au

Scales	1 : 400 @ A1
Grid	MGA
Height Datum	AHD
Drawn	GJ
Designed	GJ
Checked	AT
Approved	

Project

2 MACPHERSON STREET
WARRIEWOOD
SUBDIVISION
PACKAGE

Title

GENERAL ARRANGEMENT PLAN

Civil Engineers and Project Managers
at&l
Level 7, 153 Walker Street
North Sydney NSW 2060
ABN 96 130 882 405
Tel: 02 9439 1777
Fax: 02 9460 8413
www.atl.net.au
info@atl.net.au

Status: FOR APPROVAL
NOT TO BE USED FOR CONSTRUCTION

A1

Drawing No.	Project No.	Issue
C005	18-580	C

F:\18-580 Warriewood Meriton\6.0 Drgs\Civil\Final\000 Series - Subdivision\C005.dwg

0B2
Macpherson
Street,
Warriewood

APPENDIX B

GHD COMMENTS

10 August 2017

Wayne Williamson
Team Leader, Sydney Region East
NSW Department of Planning & Infrastructure
Level 22, 320 Pitt Street
Sydney NSW 2001

Our ref: 2126705-34527
Your ref: PO 45382343

Dear Wayne

2 Macpherson Street Planning Proposal
Review of flood assessment

1 Background

The Department of Planning and Environment has issued a Gateway determination for a Planning Proposal, which seeks to amend the Pittwater Local Environmental Plan (LEP, 2014) to permit 22 residential dwellings on land at 2 Macpherson Street, Warriewood. Northern Beaches Council has reviewed the flood assessment report and recommended additional information must be provided before the Planning Proposal can proceed to public exhibition. Northern Beaches Council does not support the Planning Proposal.

The Department needs to confirm that the proposed amendments to the LEP are satisfactory and adequately justified by appropriate flooding assessment, as these changes will allow residential development on land that has been identified as flood prone. To achieve this GHD has:

- Reviewed the observations and recommendations of the flood assessment report prepared by Bonacci Group (NSW) Pty Ltd.
- Reviewed the additional information request from the Northern Beaches Council (NBC).
- Reviewed and advise if the additional information provided in response to NBC's request is adequate.
- Recommended any additional information that could be provided or any aspects of the flooding assessment that need to be clarified.

Our findings are summarised in the following letter report of findings.

2 Correspondence Chronology

Our advice is underpinned by the chronology of correspondence/events tabulated in Table 1.

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Level 15, 133 Castlereagh Street Sydney NSW 2000 Australia
T 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com **W** www.ghd.com

Table 1 Chronology of Correspondence/Events

Date	Reference	Comments
13 October 2016	Bonacci, 2016	Original flood report in support of the Planning Proposal
31 January 2017	Referenced in NBC, 2017	Planning Proposal considered and rejected by NBC
27 February 2017	Cardno, 2017 a and b	Resubmission of Planning Proposal, answering some of the queries that NBC raised in the January 2017 rejection
10 March 2017	Referenced in NBC, 2017	Department of Planning & Environment notification to NBC of resubmission of Planning Proposal
30 March 2017	NBC, 2017	NBC comments on Planning Proposal, noting that it would not be supported. NBC also confirmed the proposal submitted for a Rezoning Review is the same proposal, as is the documentation, considered and rejected by NBC on 31 January 2017.
18 July 2017	Meriton, 2017	Additional information in addressing Point 1 of the Gateway Determination

3 Planning Matters

- The LEP, amongst others:
  - Identifies the Warriewood Valley Release Area on the Urban Release Area Map (6370_COM_URA_012_010_20150921).
  - The Urban Release Area Map identifies 2 Macpherson Street as being located in Buffer Area 1m.
  - Nominates permissible numbers of dwellings in buffer areas/sectors and notes “no dwellings” for Buffer Area 1m.
  - Identifies the subject (and adjacent) lots as “High Hazard – Affected by The Flood Planning Level (FPL) and the Probable Maximum Flood (PMF)
- The Pittwater 21 Development Control Plan (DCP, 2014), amongst others:
  - Outlines controls for Integrated Water Cycle Management, which requires compilation of a Water Management Report by appropriately qualified professionals and certified by an experienced and qualified engineer specialising in hydraulics. The purpose is to incorporate an integrated approach to water management and conservation in the design of the development, addressing water quality and quantity, watercourse and creek corridors, stormwater and groundwater, and minimises the risk posed by flooding and adapts to climate change impacts.
  - Stipulates that the Water Management Report is to be in accordance with NBC’s Warriewood Valley Urban Land Release Water Management Specification (WMS, 2001) and relevant

legislation taking into account the Narrabeen Lagoon Flood Study (September 2013 as amended) and the Pittwater Overland Flow Flood Study (2013 as amended).

  - Stipulates requirements/controls for creek corridors, flood and stormwater management in accordance with the DCP and the WMS.
  - Nominates Locality Specific Development Controls for the Warriewood Valley

- The WMS, amongst others:
  - Specifies requirements for creek corridors, for example the requirement to contain the 100-year ARI flood within the inner creek corridor.
  - Specifies requirements for stormwater quality treatment facilities, for example their location in reference to the creek corridor and above specific flood events.
  - Specifies requirements for stormwater quantity management, for example the location of stormwater volume control structures and detention basins if proposed, and their location in reference to the creek corridor and above specific flood events.

4 Assessment

- Should rezoning be approved, the development of Buffer Area 1m would likely need to comply with LEP, DCP and associated guidelines/specifications such as the WMS.
- These plans, guidelines and specifications seek to incorporate Integrated Water Cycle Management within the Warriewood Valley, supported by a Water Management Report. Furthermore, they recognise the interaction of the creek corridor, flooding and stormwater management as part of the development of sectors and buffers within the Warriewood Valley, and that these matters need to be managed in an integrated way.
- The information provided in support of the Planning Proposal (Bonacci, 2016, Cardno, 2017a and b and Meriton 2017) discuss primarily the proposed flood management of the site in isolation to the other aspects of Integrated Water Cycle Management. Flood management in the context of the WMS does not appear to be addressed, nor is it stated that the requirements of the specification will be able to be met as part of future development. Further:
  - No details are provided on the definition and impact of more frequent flood events as required by the DCP and the WMS.
  - No details are provided on the creek corridor in accordance with the WMS and containment of the 100-year ARI flood event within the inner creek corridor.
  - Preliminary details are provided on the proposed stormwater quality management strategy. If basins are proposed, their location in relation to the creek corridor satisfying the requirement for these facilities to be above stipulated flood levels in accordance with the WMS, should be provided. In addition, it is not clear, if embankments of these facilities (if proposed) were considered in the flood impact assessment.
  - Preliminary details are provided on the proposed stormwater quantity management strategy. The location of stormwater volume control structures in relation to the creek corridor, satisfying the

requirement for these facilities to be above stipulated flood levels in accordance with the WMS, should be provided.

  - The requirements for a creek corridor and stormwater treatment facilities need to be considered when determining fill platforms and assessing flood impacts. In addition, the impact on flood velocities, redistribution of flows and risk of erosion should be discussed.

- From the information provided, it is not clear what was simulated as part of the flood impact of the fill platform, as the Bonacci 201279101 (Sk02 P2) drawing seems to differ to the plans underlain on figures 1 to 4 of Cardno 2017a. In addition, there appears to be some anomaly in the geo-referencing of this image with respect to the cadastral information, making it difficult interpret the information provided on the figures.

5 Findings

It is considered that there are a number of key matters that need to be addressed under the LEP, DCP and the WMS, that demonstrate that flooding in the context of Integrated Water Cycle Management can be achieved on the site. Further information should be provided to demonstrate that guideline and specification requirements associated with the creek corridor, flood management and facilities for stormwater quality and quantity management, in accordance with the WMS, can be achieved in an integrated way at the site.

6 References

- Bonacci, 2016, letter to Meriton Group, 2 Macpherson Street, Warriewood, Flood Assessment Report, Bonacci Group (NSW) Pty Ltd, Ref: 2021791, 13 October 2016
- Cardno 2017a, letter to Meriton Group, 2 Macpherson Street, Warriewood - Addendum Flood Impact Assessment, Ref 59917042\Lt02:DW, 27 February 2017
- Cardno 2017b, report to Meriton Group, Flood and Emergency Management Plan 2 Macpherson Street, Warriewood, 59917042, 27 February 2017
- NBC, 2017, letter to Department of Planning & Environment, Re: Request for a Rezoning Review – 2 Macpherson Street Warriewood (PGR_2017_NBEAC_001_00), Ref: 2017/085100, 30 March 2017
- Meriton 2017, letter to Department of Planning & Environment, Gateway Determination – 2 Macpherson Street, Warriewood, Department reference: PP_2017_NBEAC_003_00, 18 July 2017
- LEP 2014, Pittwater Local Environmental Plan
- DCP, 2014, Pittwater 21 Development Control Plan
- WMS, 2001, Warriewood Valley Urban Land Release Water Management Specification (2001), Pittwater Council, 2001

Sincerely
GHD Pty Ltd

Dr Rainer Berg
Principal Civil Engineer
+61 2 8898 8815

0B2
Macpherson
Street,
Warriewood

APPENDIX C

FLOOD EMERGENCY MANAGEMENT PLAN

Flood and Emergency Management Plan

2 Macpherson Street, Warriewood

59917042

Prepared for
Meriton Group

5 December 2019

Cardno
Shaping the Future

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Global Senior Principal

Document Information

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Version Number	Rev5
Effective Date	05/12/19

Document History

Version	Effective Date	Description of Revision	Prepared by:	Reviewed by:
Rev1	21/02/2017	For Review	Daniel Wood	
Rev2	22/02/2017	For Submission	Daniel Wood	Andrew Reid
Rev3	27/02/2017	For Submission	Daniel Wood	Andrew Reid
Rev4	15/01/2019	For Submission	Timothy Shen	Daniel Wood
Rev5	05/12/2019	For Submission	Timothy Shen	Brett C Phillips

Executive Summary

A flood emergency management plan of 2 Macpherson Street, Warriewood has been developed to identify and mitigate the risk of flooding onsite. Without the necessary civil works and filling, the site is currently considered to have a high flood risk due to its location within the Narrabeen Creek and Narrabeen Lagoon Floodplain.

As part of the proposed development, it is proposed to provide a minimum finished floor level of the PMF event, exceeding the requirements of the Pittwater Local Environment Plan. This proposed floor level significantly improves the flood immunity of the site as the buildings are protected against the majority of flooding.

For events which result in water levels greater than the finished floor level being the PMF (generally considered to have an equivalent AEP of between 0.0001% and 0.00001% AEP), it has been established that Shelter-in-Place is necessary to ensure the residual risk of flooding is managed for the site.

The analysis of the residual risk undertaken has shown:

- There is insufficient time to rely upon evacuation for the site;
- The dwellings onsite can accommodate for refuge on both ground and second story;
- The isolation time for the site is approximately 4 hours for the site and Macpherson Street, thus the flood risk to life associated with Shelter-in-Place isolation is expected to be negligible.
- The development of the site will not require the dwellings to be specially engineered to ensure structural stability.

The assessment undertaken confirms that the development, if undertaken in accordance with the measures proposed within this document will not result in a significant increase to risk of property or life.

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Figures

Appendices

Glossary

Average Recurrence Interval (ARI)	The long-term average period between occurrences equalling or exceeding a given value. For example a 20 year ARI flood would occur on average once every 20 years.
Annual Exceedance Probability (AEP)	The probability of an event occurring or being exceeded within a year. For example a 5% AEP flood would have a 5% chance of occurring in any year. An approximate conversion between ARI and AEP is provided.

AEP	ARI
63.2 %	1 year
39.3 %	2 year
18.1 %	5 year
10 %	10 year
5 %	20 year
2 %	50 year
1 %	100 year
0.5 %	200 year
0.2 %	500 year

Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Flood	The covering of normally dry land with water from a stream, river, estuary, lake, dam, major drainage and/or due to super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
Freeboard	A height added to flood levels to provides reasonable certainty that the risk exposure accepted by deciding on a particular flood is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, driveway crest levels, etc.
Probable maximum flood (PMF)	The largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain.

1 Introduction

In order to manage the flood risk associated with the proposed development of 2 Macpherson Street, Warriewood a flood emergency management plan for the site has been prepared. As part of the proposed development it is proposed to provide a minimum finished floor level of the PMF event of 4.9 mAHD.

This proposed floor level ensures flood immunity of the site as the buildings are protected against the majority of flooding. The site however will become isolated in PMF event for approximately 4 hours. The depth of inundation across Macpherson Street in the PMF event reaches a maximum of 600 mm

The purpose of this document is to provide confidence to Council that the residual flood risk for events in excess of the 0.01% AEP flood has been appropriately considered. The document also highlights appropriate management solutions to ensure that the risk to property and life in these extreme events is understood and appropriately mitigated.

1.1 Site Characteristics

The proposed development site is located at 2 Macpherson Street, Warriewood .The site comprises approximately 2.1 Hectares of land at 2 Macpherson Street (the site) in Warriewood Valley. Legally, the site is described as Lot 25 Section C in DP5464 and is shown in Figure 1.

The parcel of land is of an irregular shape has a 120 metre frontage to Macpherson Street to the south. A central portion of the site has been raised and levelled and is currently surrounded by undeveloped land. Levels across the site range from 1.4m AHD in the northern section of the site (within the creek) to a high point of 3.7 mAHD within the central portion of the site.

Figure 1-1 Site Locality Plan (Source – Urbis)

1.2 Relevant Documents

The report has regard to the following documents:

- Floodplain Development Manual by NSW Government (April 2005);
- Pittwater Local Environment Plan (LEP) 2014;

1.3 Statutory Requirements

A recent review of the previous application submission has identified that insufficient information was provided to determine the development could meet the objectives of Clause 7.3 (Flood planning) in the Pittwater LEP 2014, specifically:

- *to minimise the flood risk to life and property associated with the use of land; and*
- *to allow development on land that is compatible with the land's flood hazard, taking into account projected changes as a result of climate change*

In order to address the above concerns this document has been developed.

In addition to council requirements NSW government Section 117 Local Planning Direction 4.3 has also been considered and achieved where relevant.

1.4 Previous Investigations

Previous relevant investigations for this site include:

- Narrabeen Lagoon Flood Study (BMT WBM 2013);
- Narrabeen Lagoon Floodplain Risk Management Study and Plan Stage 3 & Stage 4 Interim Report (Cardno, 2016);
- Flood Impact Assessment for 2 Macpherson Street, Warriewood (Cardno, 2018).

1.5 Format of this Document

The format of this document is as follows:

- **Section 2** describes the flood behaviour on the site discusses the risks present to the site under the proposed development; and
- **Section 3** discusses the proposed flood protection measures to be incorporated into the development; and
- **Section 4** discusses the proposed flood evacuation measures to be employed on the site to account for flood events that exceed the flood protection level; and
- **Section 5** provides a summary of the findings of the assessment

2 Flood Behaviour

Floods are discussed in terms of how likely the flood is to occur or be exceeded in any given year. This is called the Annual Exceedance Probability or “AEP”. A flood that occurs on average every 100 years has a 1 % chance of occurring in any given year. Larger floods do occur, although they have less chance of occurring in any given year.

The site is subject to both flooding from Narrabeen Creek and the Narrabeen Lagoon Floodplain. Results from the Narrabeen Lagoon Flood Study (WBM BMT, 2013) indicate that Macpherson Street in its current arrangement is overtopped in the 1% AEP due to the flow present in Narrabeen Creek and the influence of backwater from Narrabeen Lagoon. In the PMF event the area is significantly inundated due to the levels present in the Narrabeen Lagoon Floodplain.

Macpherson Street has been recently upgraded. This has resulted in the roadway having a level of immunity greater than 1% AEP with 30% climate change and 0.9 m sea level rise. The road will not be trafficable for approximately 4 hours in the PMF event and is inundated to depths up to 600 mm.

2.1 Flood levels

Each LGA generally defines a flood planning level based upon an AEP with an allowance for freeboard to cater for uncertainties. In the Pittwater LGA, where the proposed development results in an *intensification of development* the flood event that is utilised as the flood planning level is the 1% AEP with 30% climate change and 0.9 m sea level rise. A freeboard of 0.5 m above this level is expected for all proposed dwellings.

The dwellings onsite will not be inundated by floodwaters in PMF event and therefore also immune to the 1% AEP with 30% climate. The defined flood level for this site in this event is 3.79 mAHD.

The floor levels for all residential lots within the proposed development is 4.9 mAHD. This exceeds the required Flood Planning Level for the site of 4.29 mAHD. All proposed residential dwellings will be two storeys.

Based on information provided within Narrabeen Lagoon Flood Study (WBM BMT, 2013) this FPL is noted to be in excess of the predicted flood levels of the 0.1% AEP event under existing catchment conditions, with a freeboard of 1400 mm present on this AEP scenario.

In no event is flood water predicted to enter the dwellings.

2.2 PMF Flood Event

The PMF Event is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation coupled with the worst flood producing catchment conditions. The PMF event is generally considered to have an equivalent AEP of between 0.0001% and 0.00001% AEP.

Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. To meet Council considerations for this specific site, PMF immunity has been provided for the lots. The surrounding roadway however will have some temporary isolation in a PMF event.

The purpose of utilising the PMF flood event within an assessment is to ensure the residual risk (that is the risk that exists once the flood immunity of a development is exceeded) that is present onsite is considered and planned for. The proposed lots do not present any residual risk as the FFL has been set to the PMF level of 4.9 mAHD. The internal road way and Macpherson Street however experience inundation depths of 500mm and 600 mm respectively in the PMF event.

Figure 2-1 provides an overview of the flooding experienced within the Narrabeen Lagoon area at a catchment level in the existing flood conditions. In the PMF flood event over 3000 properties are flood affected, with almost 1400 dwellings experiencing over floor flooding (Cardno, 2016).

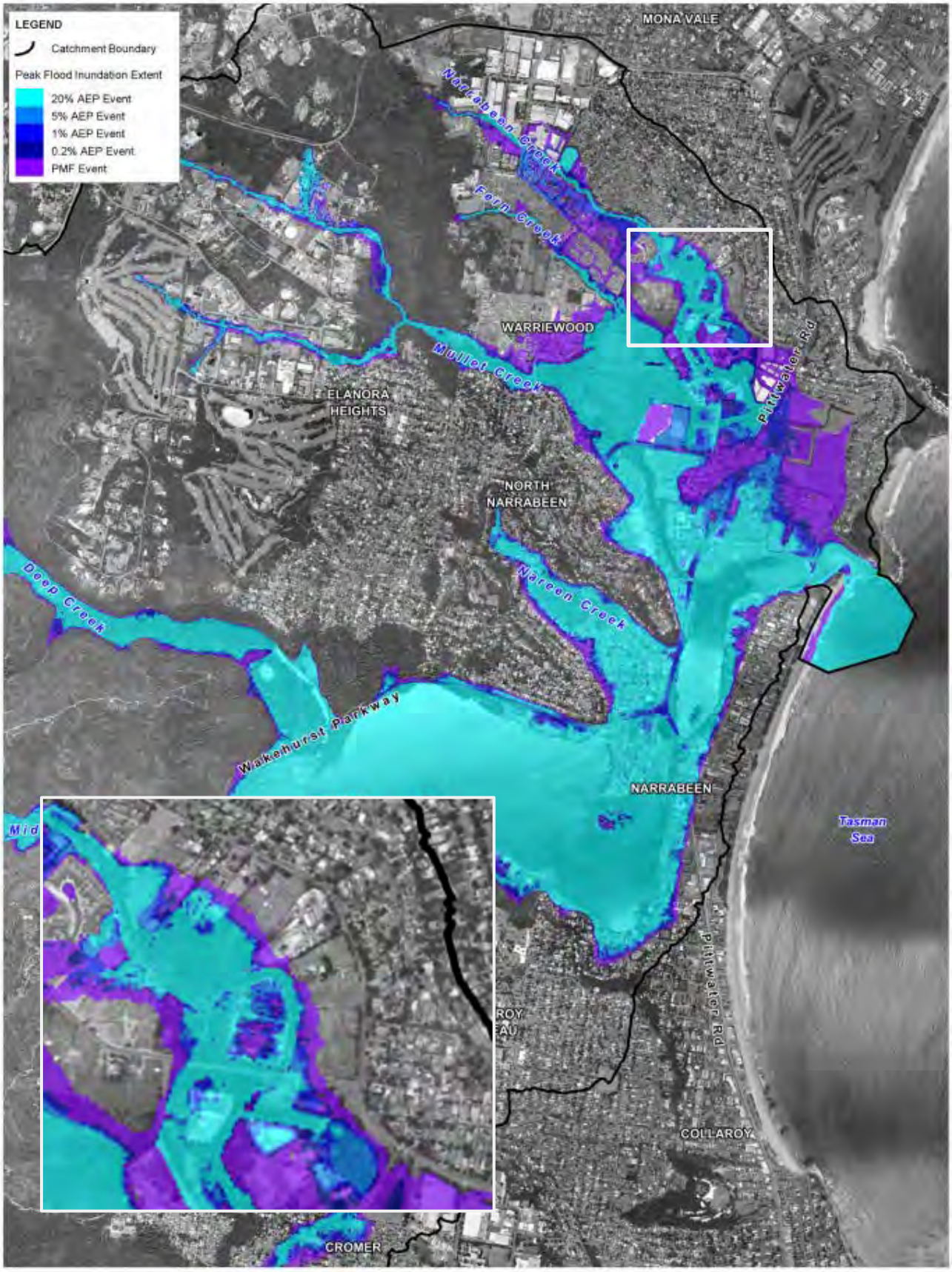

Figure 2-1 Peak Flood Extent – Catchment Derived Events (source Narrabeen Lagoon Flood Study, BMT, 2013)

FAST FACTS

In the 1% AEP with 30% climate change and 0.9 m sea level rise,

- **The internal roadway not be flooded.**
- **The dwellings will not be flooded.**

In the probable maximum flood (PMF),

- **The internal roadway, will be inundated up to 0.5 m deep.**
- **The dwellings will not be flooded.**

2.3 Flood Warning Times

Narrabeen Lagoon Floodplain Risk Management Study and Plan Stage 3 & Stage 4 Interim Report (Cardno, 2016) indicates the PMF event likely to impact the development site is the 6 hour PMF duration. This event dominates all areas influenced by the Narrabeen Lagoon flood level well beyond the site. Additional analysis of this event, and alternative PMF events has been undertaken to confirm this mechanism. This assessment is provided in Appendix A.

The internal roadway within the development is expected to be overtopped in this event approximately 3.0 hours after the onset of the PMF rainfall event. Similarly, after 3 hours Macpherson Street is expected to be overtopped by up to 800 mm.

The short warning times means that in the case of a PMF event, there would be insufficient time to evacuate any residents and/or visitors from the site and that instead residents and/or visitors would need to Shelter-in-Place.

In events less extreme than the PMF but of sufficient severity to overtop the internal roadway a Shelter-in-Place emergency response should still be followed.

The expected time that visitors and/or residents would need to Shelter-in-Place would be around 4 hours in a PMF, assuming no evacuation once floodwaters exceed the roadway.

2.4 Flood Hazard

2.4.1 1% AEP Flood

For events up to and including the 1% AEP flood, the subject site, including the internal roadway are not flood affected. The Macpherson Street upgrade now ensures flood immunity in this event and as such evacuation both east and west along Macpherson Street is available.

2.4.2 1% AEP with 30% climate change and 0.9 m sea level rise

In the 1% AEP flood with 30% climate change and 0.9 m sea level rise, the residential dwellings onsite and internal roadway servicing the dwellings are not innundated. Macpherson Street will also not be flooded and thus access and egress possible. **Figure 2-2** shows the predicted impact of this event.

2.4.3 Extreme Floods

In the PMF (generally considered to have an equivalent AEP of between 0.0001% and 0.00001% AEP), the surrounding roads will be flooded by creek flows and the Narrabeen Lagoon backwater. The onsite dwellings will be flood free. Water depths will increase by up to 1 m over the 1% AEP with 30% climate change and 0.9 m sea level rise flood level. Note that no hazard is predicted within the dwellings onsite as they are above the PMF flood level.

Residents and visitors will be required to either evacuate or remain within the Shelter-in-Place prior to the event occurring. Due to the short flood warning times available for the site Shelter-in-Place is considered the safest approach to flood management in this event.

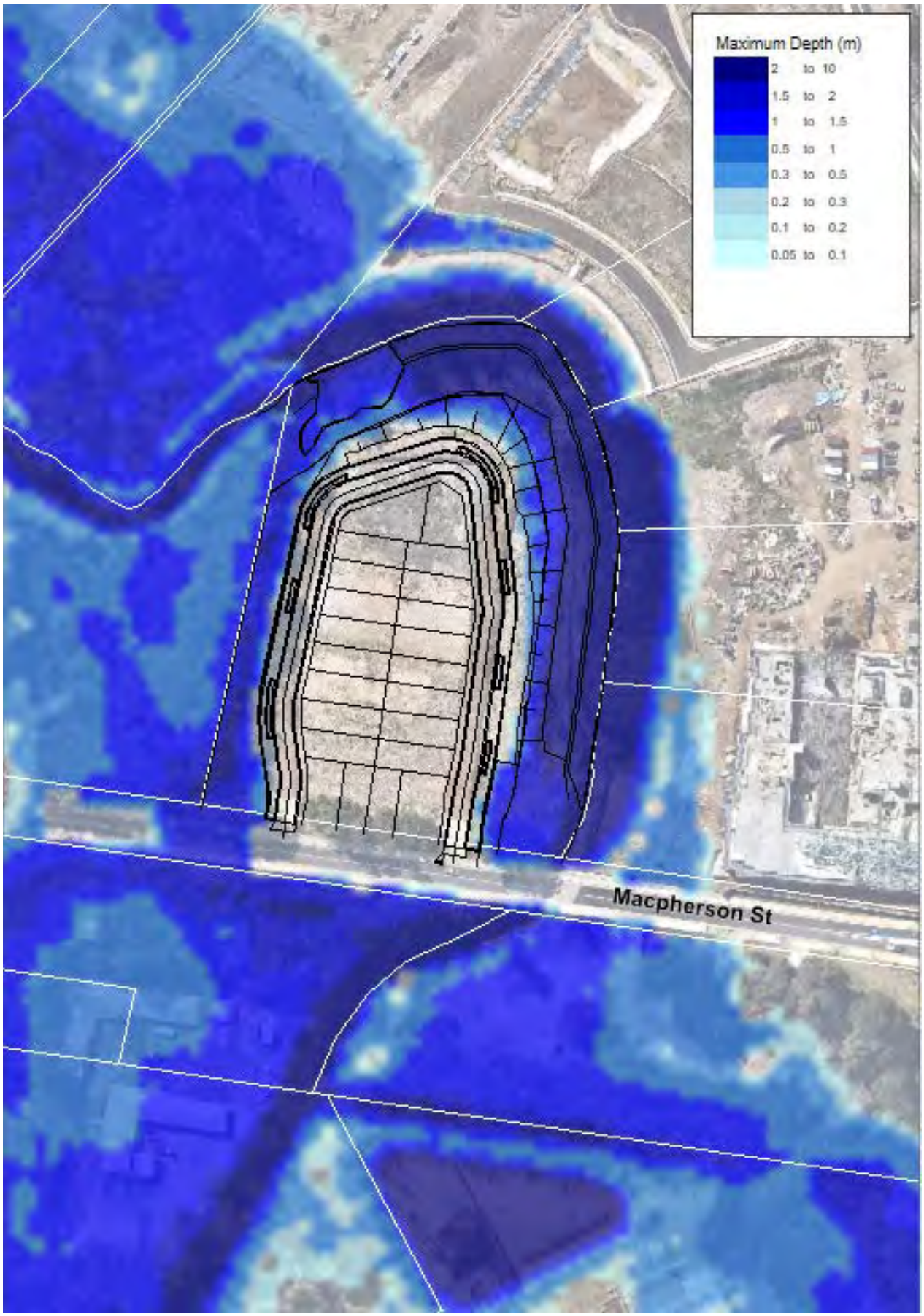

Figure 2-2 1% AEP with 30% climate change plus 0.9m sea level rise Peak Depth

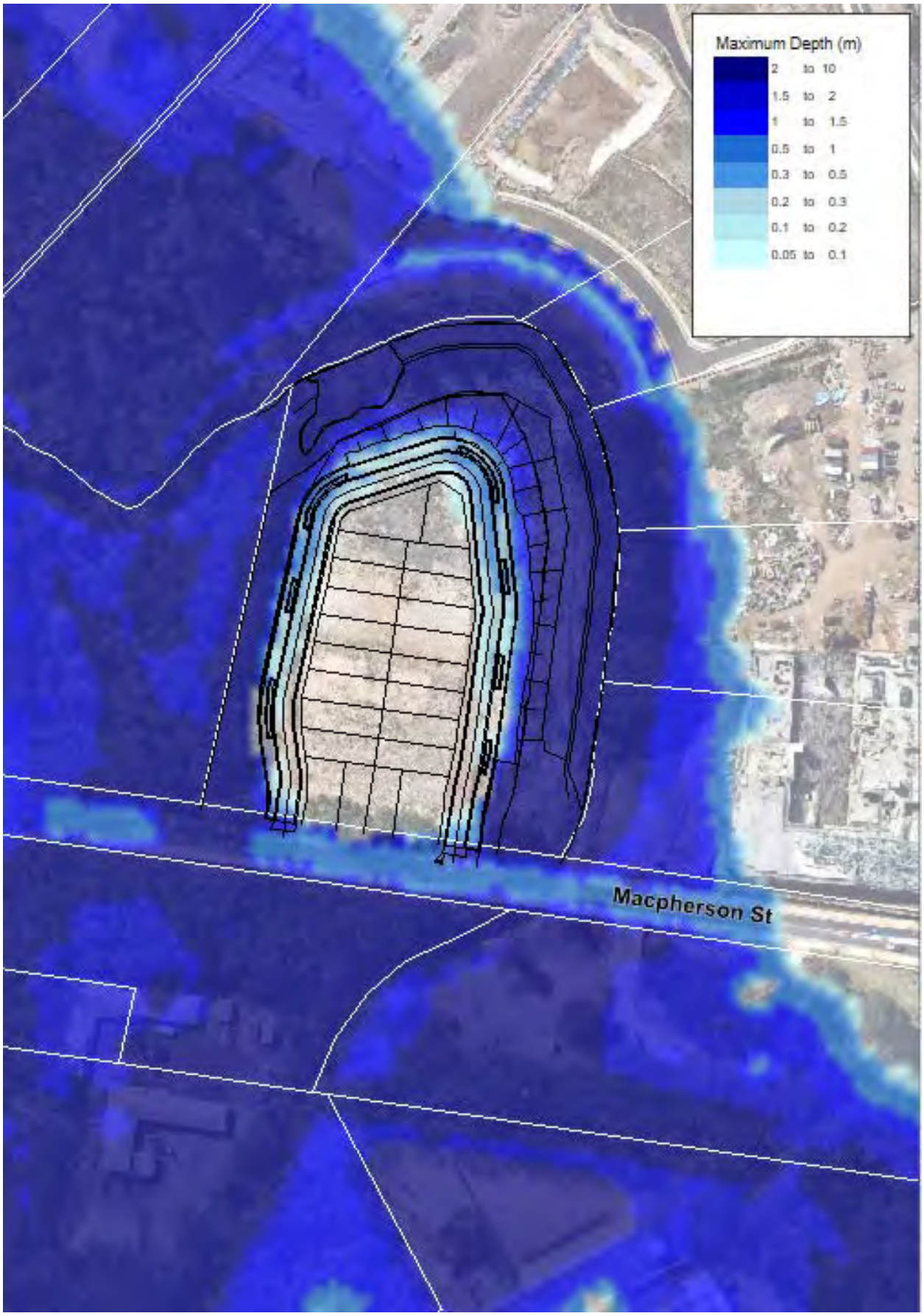

Figure 2-3 PMF Peak Water Depth

3 Flood Protection Measures

This section discusses the proposed flood protection measures that are proposed to be incorporated into the development. Protection for events up to and including the 1% AEP flood with 30% climate change and 0.9 m sea level rise is provided by permanent measures, namely the raised habitable floor levels.

3.1 Floor levels

The Pittwater LEP 2014 defines the Flood Planning Level in Section 7.3 Flood Planning, under Item (5):

Flood planning level *means the level of a 1:100 ARI (Average Recurrent Interval) flood event plus 0.5 m freeboard, or other freeboard determined by an adopted floodplain risk management plan.*

Additionally, Section B3.23 – Climate Change (Sea Level Rise and Increased Rainfall Volume) of the Pittwater 21 DCP, states that for any "intensification of development" climate change must be considered. The consideration for climate change at present includes a 30% rainfall increase (as adopted by Council on 15/02/2010) with 0.9m sea level rise (as adopted by Council on 7/12/2009). "Intensification of development" includes but is not limited to:

- An increase in the number of dwellings (but excluding dual occupancies and secondary dwellings); and
- An increase in commercial or retail floor space.

As this site will result in an intensification of development the minimum floor level required has been assumed to be the 1% AEP flood with 30% climate change and 0.9 m sea level rise plus 0.5 m freeboard. Based on flood mapping undertaken as part of Narrabeen Lagoon Flood Study (BMT WBM, 2014) and advice provided by Councils, the flood level of this event is 3.79 mAHD. Thus, with a 0.5 m freeboard incorporated the flood planning level is 4.29 mAHD.

The proposed finished floor levels are at the PMF flood level (4.90 mAHD) and thus exceed the current Council policy and surrounding developments.

As the floor levels are greater than the PMF event, shelter in place refuge onsite is proposed in events where surrounding roadways are inundated.

3.2 Flood Awareness

In addition to the above, residents and visitors to the site should be made aware of the flood hazard and evacuation procedures through a combination of measures:

- Information regarding the flood risk and evacuation procedures for the site should be provided on each dwelling to ensure all occupants are aware of the procedure.
- Occupants should be encouraged to prepare a FloodSafe Plan. Information regarding this process should be provided to all owners either through signage onsite (in the power box for example) or through information provided to residents upon moving in.

3.3 Flood Warning

While the warning systems discussed below are not specific to the site they are important to highlight the information that is available to the public to inform them of a developing event. Similar to the development of a FloodSafe Plan, residents should be encouraged to familiarise themselves with the flood warning systems in the area.

3.3.1 Observation of local rainfall or flood water

An important indication of likely imminent flood activity would be intense local rainfall. Northern Beaches Flood Information Network http://www.mhl.nsw.gov.au/users/NBFloodWarning/ provides information regarding water levels and rainfall as well as information regarding flood preparedness.

3.3.2 The Bureau of Meteorology

The Bureau of Meteorology does not prepare flood predictions for the Narrabeen Lagoon, but does issue Severe Thunderstorm Warnings and Severe Weather Warnings for Sydney.

Severe Thunderstorm Warnings are issued together with maps indicating the current location and predicted path of thunderstorms. Severe Weather Warnings are for severe weather not related to thunderstorms, cyclones or fire, but for other causes of intense rainfall or storm surge, such as “east coast lows”.

These warnings are available at http://www.bom.gov.au/nsw/warnings/.

BoM also provides real time rain radar coverage for Sydney at http://www.bom.gov.au/products/IDR713.loop.shtml.

3.3.3 The NSW SES (Emergency Phone Number 132 500)

The local SES unit is Warringah- Pittwater which operates a facebook page for informing members of the public (https://www.facebook.com/WPWSES/). The applicable region is the Sydney Northern Region, which operates also operates a facebook page (https://www.facebook.com/NSWSESSNR/).

The SES issues Local Flood Advices. These are issued on the basis of localised valley watch information for locations for which the BoM does not issue Flood Warnings. They normally predict which class of flooding (minor, moderate or major) will occur, and must not contradict any Flood Warnings provided by the BoM for other gauges on the same river. Local Flood Advices are to be clearly identified as being issued by the SES.

At the time of writing, a Draft Flood Warning Plan had been prepared the NSW SES. However, this draft was prepared a number of years ago and the timing for finalisation is uncertain.

3.3.4 Local Emergency Management

Local emergency management plans are prepared to avoid burdening local emergency management with additional responsibilities.

Based on a review of available information it does not appear that a local emergency management plan is available in the public domain for this region. In the absence of this information the Manly-Warringah-Pittwater Disaster Plan (DISPLAN) (MWPLEMC, 2005) or the North West Metropolitan Emergency Management District DISPLAN (Interim) (NWMDEMC, 2011) should be utilised.

3.3.5 Local television and radio stations

Local television and radio stations would disseminate warnings from the Bureau of Meteorology, SES and other relevant sources. The local radio station for emergency information is 702 ABC.

4 Flood Evacuation

The proposed floor level of the dwellings cater for the majority of events however surrounding roadways may become inundated. In events that result in flood levels greater than the 1% AEP flood with 30% climate change and 0.9 m sea level rise Macpherson Street and the internal road may become inundated.

Due to the likely short timeframe of (approximately 3 hours) available between the beginning of rainfall and the onset of flooding in extreme rainfall events, Shelter-in-Place has been proposed as the flood emergency measure utilised on this site. The following section details the analysis undertaken as to why this is the most appropriate emergency management option available for the site and the mechanisms to be put in place to ensure the risk to life under this approach is minimal.

4.1 Flood Evacuation Timeline

4.1.1 Background

A key consideration as to the appropriate flood evacuation policy in place on a development is the available flood evacuation time. The NSW SES Timeline Evacuation Model has been the de facto standard for evacuation calculations in NSW since it was first developed for evacuation planning in the Hawkesbury Nepean Valley. Though the guideline has not yet been released, the paper *Technical Guideline for SES Timeline Evacuation Model* was prepared by Molino et al. (2013) to brief the industry on the use of the guideline.

The timeline assessment of evacuation potential relates to the time required for regional evacuation of floodplains from doorknocking by SES volunteers through to the evacuation of all occupants from the region.

At the centre of the timeline methodology is the following concept:

Surplus Time = Time Available – Time Required

If surplus time is positive then evacuation of all occupants is feasible, while a negative value implies evacuation of all occupants is not likely to be achieved.

An analysis of the proposed development within the regional Narrabeen Lagoon floodplain has been undertaken utilising the above methodology.

4.1.2 Time Available

This variable is dependent on the rate of rise of waters, meaning it varies for each evacuation scenario. The proposed development lies within the lower Narrabeen Lagoon floodplain. As the lower Narrabeen Lagoon floodplain, from lower South Creek to Warriewood Valley, is an inter-connected storage area the water level time series for the majority of the floodplain is nearly identical regardless of the location of development within the floodplain.

The proposed development is to have floor levels equal to the PMF flood level. As such inundation of the dwellings is unlikely. The surrounding roadways however may be subject to inundation in this event.

The times to reach inundation after the onset of rainfall for the PMF flood event is 3.0 hours to inundation of the internal roadway and Macpherson Street. As the internal roadway is part of the only safe evacuation route this is considered the critical timeline for this assessment.

It should be noted that theoretical flood events do not always match actual events and the time to reach inundation after the onset of rainfall may be shorter or longer than listed here.

4.1.3 Time Required

The SES evacuation timeline model uses the following equation to calculate Time Required:

Time Required = Warning Acceptance Factor (WAF) + Warning Lag Time (WLT) + Travel Time (TT) + Travel Safety Factor (TSF)

Where the following values are recommended in the guideline:

WAF = 1 hour – accounts for the delay between occupants receiving the evacuation warning and acting upon it.

WLT = 1 hour – an allowance for the time taken by occupants to prepare for evacuation.

TT = Variable – the number of hours taken for the evacuation of all vehicles based on road capacity. NSW SES recommend a road lane capacity of 600 vehicles per hour. Since there are many evacuation routes to flood-free land across the Narrabeen Lagoon floodplain the Travel Time is assumed to be negligible (in the order of minutes, not hours).

TSF = Variable – added to travel time to account for any delays along the evacuation route, resulting from accidents for example, this value is a variable of TT between 1 hour and 3.5 hours.

Note that Time Required is calculated from the time that SES have mobilised and are ready to begin doorknocking. Before this time there are two additional considerations.

- Forecast and actual rainfall monitoring – in the case of Narrabeen Lagoon tools for flood forecasting to inform flood evacuation are inadequate. Actual rainfall monitoring is the only feasible warning system. The flood warning system that is in place is the Northern Beaches Flood warning system (MHL, 2014), which recommends response only after 3 hours of sustained heavy rainfall.
- Mobilisation – the time taken for SES to mobilise and travel to residences to commence doorknocking. There is no data available on mobilisation time for local SES services, so this has not been included in the evacuation timeline for Narrabeen Lagoon.

Based on the above contributors, the overall time required for evacuation of the Narrabeen Lagoon floodplain is a minimum of 5 hours (2 hours for WAF and WLT, 3 hours for actual rainfall monitoring). It should be noted that this is a low bound estimate, as various factors such as Travel Time, Travel Safety Factor and SES mobilisation have been disregarded.

4.1.4 Surplus Time

For this development the surplus time is negative, because the time available (150 minutes for the PMF 360 minute storm) is less than the time required to evacuate (minimum of 5 hours).

Under the current flood warning system and the existing provisions available, there is insufficient time to safely assume evacuation of the site based on SES doorknocking and assisted evacuation. Based on this outcome Vertical Evacuation, or Shelter-in-Place is considered the most appropriate evacuation solution for this site.

4.2 Shelter-in-Place

Shelter-in-Place is a feasible form of emergency response for some parts of the Narrabeen Lagoon floodplain. In accordance with the Australasian Fire and Emergency Service Authorities Council (AFAC) guideline, where localised evacuation is not possible, Shelter-in-Place is seen as an acceptable alternative if designed appropriately.

Shelter-in-Place in this instance has been selected as the best solution for the site as the evacuation timeline (refer Section 4.1) indicates that the time available prior to the PMF flood event inundating the site is less than the required time to evacuate.

The Shelter-in-Place approach is utilised throughout Warriewood as the primary flood management technique due to the large extent of flooding experienced within the PMF event. The proposed development has a prescribed finished floor level that will ensure that the development encounters flooding in only very unlikely events. The following sections detail the assessment undertaken to ensure Shelter-in-Place is a suitable emergency management measure.

4.2.1 Refuge Area

The proposed development is to consist of 22 dwellings, all of which will be two storey. All dwellings are to be built at or above the PMF event and thus the entire dwelling, in a PMF event, will be flood free.

4.2.2 Duration of Inundation

Duration of inundation relates to the length of isolation of any Shelter-in-Place refuges within the floodplain. Isolation results in the following sources of risk to life.

- Isolation from medical services – in the event of a medical emergency, a pre-existing condition, injury, or sudden onset event such as heart attack, medical services may not be accessible. This is a particularly high risk for developments occupied by vulnerable residents who are more likely to experience a medical emergency at any given time than other demographics. It is not considered that this development would be more vulnerable to events of this nature than any other development in the area.
- Isolation from supplies – including drinking water, food, amenities, and communication lines. This becomes a particular concern when the period of isolation exceeds 24 hours.

In the 6 hour PMF event the duration of inundation is expected to be approximately 4 hours. Since the duration of inundation is expected to be sub-daily for the site and Macpherson Street, the flood risk to life associated with Shelter-in-Place isolation is expected to be manageable through provision of supplies and services to the refuge.

It is considered that if the Shelter-in-Place approach is appropriately implemented then the increased risk to life due to the presence of the development will be negligible.

4.2.3 Egress from Site

The area surrounding the site will be inundated in events greater than the 1% AEP, and therefore egress from the site is not recommended during flood events.

4.2.4 Evacuation Routes

For events up to and including the 1% AEP flood, the subject site, including the internal roadway are not flooded. The Macpherson Street upgrade now ensures flood immunity in this event and as such evacuation both east and west along Macpherson Street is available.

In the 1% AEP flood with 30% climate change and 0.9 m sea level rise, the residential dwellings onsite and the internal roadway servicing the dwellings are not flooded.

As the intensity and final level of flooding that may be experienced onsite is difficult to predict the general policy for the site in all events of elevated flood waters would be to remain onsite until flood waters recede.

4.2.5 Evacuation Centres

Evacuation centres are not proposed as the initial place of refuge, as vertical evacuation to higher floors is safer and egress from the site will be limited.

4.2.6 Structural Stability

The collapse of a Shelter-in-Place refuge could result in loss of life and therefore is not acceptable under any flood event. By utilising the Combined Flood Hazard Curves (Source: Commonwealth Government, 2014) shown in Figure 4-1, it is possible to identify approximate levels of structural stability for the following structures:

- All normal structures are assumed to have structural stability up to and including Hazard Category H4; and
- All specially engineered structures are assumed to have structural stability up to and including Hazard Category H5.

Based on the information provided within Narrabeen Lagoon Floodplain Risk Management Study and Plan Stage 3 & Stage 4 Interim Report (Cardno, 2016), the undeveloped site is based in an area of H4-H5 Hazard.

In the proposed development conditions the increased ground levels onsite will result in no flooding of the dwellings. As such no hazard is recorded.

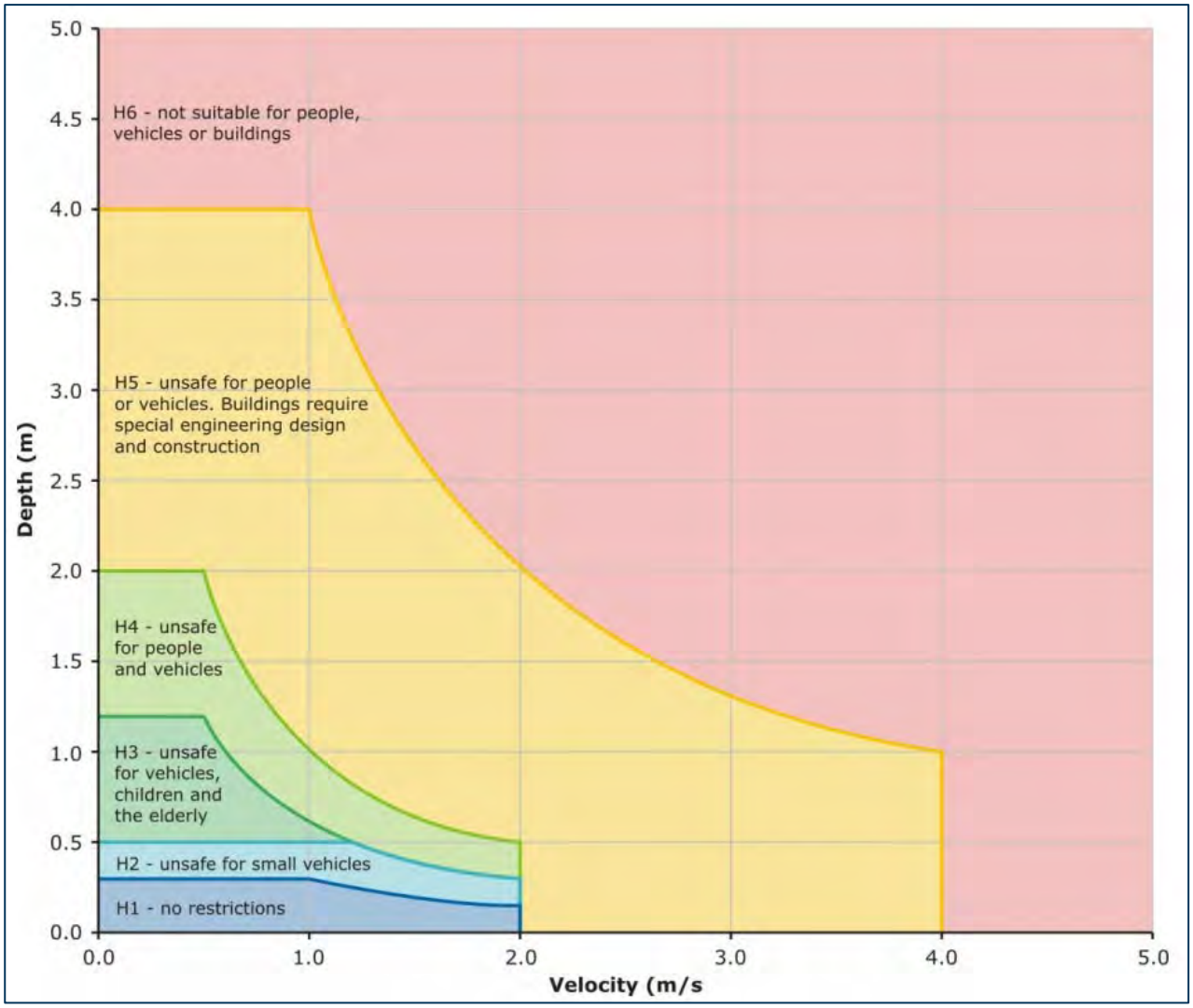

Figure 4-1 Combined Flood Hazard Categories (Source: Commonwealth Government, 2014)

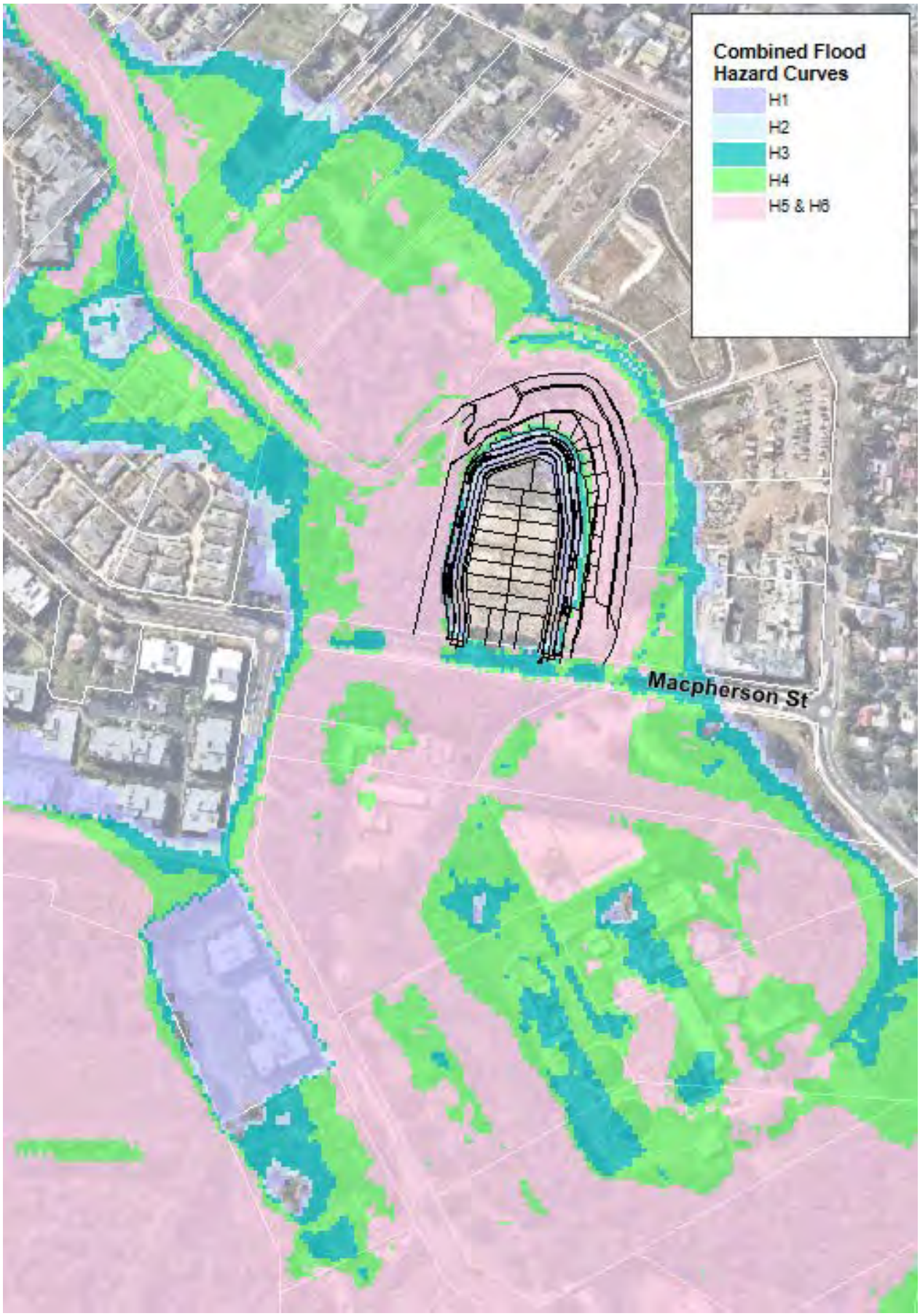

Figure 4-2 PMF Event – Combined Flood Hazard Category Results for the Developed Site

5 Conclusions

In order to determine and manage the flood risk associated with the proposed development of 2 Macpherson Street, Warriewood a flood emergency management plan for the site has been developed. The site in its existing condition is considered to have a high flood risk due to its location within the Narrabeen Creek and Narrabeen Lagoon Floodplain. As part of the proposed development a minimum finished floor level of the PMF event is proposed.

This proposed floor level significantly improves the flood immunity of the site as the buildings are protected against the majority of flooding.

For events greater than the 1% AEP flood with 30% climate change and 0.9 m sea level rise plus 0.5 m freeboard it has been established that Shelter-in-Place is both necessary for the development of the site and, with appropriate implementation, ensure the residual risk of flooding is managed for the site. This is due to the potential isolation of the site due to the surrounding roadways being inundated.

The analysis of the residual risk undertaken has shown:

- There is insufficient time to rely upon evacuation for the site requiring a Shelter-in-Place response;
- The dwellings onsite being two storey can accommodate for shelter on either storey;
- The isolation time for the site is sub daily for the site and Macpherson Street, thus the flood risk to life associated with Shelter-in-Place isolation is expected to be negligible.
- The development of the site will not require the dwellings to be specially engineered to ensure structural stability.

Based on the outcomes of this assessment it is considered that the implementation of dwellings with a finished floor level of the PMF event, coupled with a Shelter-in-Place emergency evacuation policy for events that inundate the surrounding roadway will not result in a significant increase to risk of property or loss of life.

0B2
Macpherson
Street,
Warriewood

APPENDIX
A

PMF REVIEW

Our Ref: 59917042:DW
Contact: Daniel Wood

14 January 2019

Meriton Group
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Attention: Walter Gordon

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Dear Sir,

2 MACHPHERSON STREET WARRIEWOOD - PMF FLOOD CONDITION AND TIME OF ISOLATION ASSESSMENT

As part of ongoing Court Proceedings (case number 2018/244034) upon 2 Macpherson Street, Warriewood it was identified that the site, while in accordance with the general requirements to achieve shelter-in-place set by Council, may be subject to times of isolation of greater than 6-hours in a PMF event.

The Council DCP states that under these circumstances, in non-land release areas, a minimum land area above the PMF level of 2m^2 per occupant is required when assuming a shelter-in-place evacuation procedure (B3.13, Control 3). Council is of the opinion that because this site is located within a land release area, it is subject to greater scrutiny. It is noted that no specific measure of this is provided within the DCP.

During the Section 34 meeting, it was highlighted that the site, in its proposed form, would meet the requirements of the DCP and have, in a 6-hours (critical water level) PMF event, a period of approximately 3 hours when the road would be closed. Each potential lot onsite would exceed the 2 m^2 of flood free area above the PMF required for shelter in place for isolation times greater than 6 hours. While the key DCP criteria have been met, council considered that, due to the land release nature of the site, a greater level of rigour, was required in the assessment of the site. It was postulated that, while the peak water level in a PMF event may occur in the 6-hours event, a longer duration PMF event may result in a longer time of isolation.

As identified within the Section 34 proceedings, no longer-duration flooding has previously been assessed within the Narrabeen Lagoon Catchment. In order to assess the site for this mechanism of flooding in a time and cost effective manner, it was agreed within the proceedings to undertake the assessment within the hydrologic model rather than the hydraulic model. Based on this position, the following approach was established during the proceedings:

- Undertake a review of current best practice PMP and PMF assessments, relevant to the Narrabeen Lagoon Catchment;
- Develop Rainfall Depths for the longer duration PMP events in accordance with current best practice;
- Update the current Narrabeen Lagoon Hydrologic Model to incorporate the developed PMP rainfall depths and appropriate temporal patterns
- Run the hydrologic model to determine the flow at the site and at the Narrabeen Lagoon Entrance
- Undertake an assessment and prepare a discussion of the findings and then determine the implications of the findings relevant to flood level and time of isolation of 2 Macpherson Street.

Narrabeen Lagoon Catchment Characteristics

The Narrabeen Lagoon catchment is located on the northern edge of the Warringah LGA and the south eastern edge of Pittwater LGA on Sydney's northern beaches. The catchment occupies a total area of approximately 55km^2 and drains to the Tasman Sea through a narrow channel to the lagoon entrance at North Narrabeen Beach (*Narrabeen Lagoon Flood Study*, BMT, 2013).

2 Macpherson Street, Warriewood, is located within the Narrabeen Creek sub-catchment of the Narrabeen Lagoon Catchment. However, the location of the site means that during very severe flood events that cause extreme water levels in Narrabeen Lagoon, that it has the potential to be affected by the backwater associated with the event.

Within the Narrabeen Lagoon Flood Study (BMT, 2013) the PMF has been assessed for events up to the 6-hours duration. This information is deemed accurate and has not been revised for this task. In the previously assessed 6-hours PMF, due to the inflow reaching the entrance of the lagoon and exceeding the discharge capacity of the entrance, water levels in the lagoon reach approximately 4.85 mAHD.

Chart 1 shows the time series results associated with this event based on the modelling undertaken as part of the *Narrabeen Lagoon Flood Study* (BMT, 2013). During the 6-hours PMF event, flows from the catchment into the lagoon exceed 1800 m^3/s. At the time of this peak flow into the lagoon, discharge through the entrance is approximately 1450 m^3/s. As the water levels within the lagoon rise, the entrance scours out, thereby increasing its effective discharge capacity. The discharge capacity in this event, at its maximum, reaches approximately 1500 m^3/s.

During the 6-hours PMF event, Macpherson Street suffers inundation for approximately 4 hours and is 'untrafficable' for approximately 3 hours. The closure occurs when the discharge into the lagoon is approximately 1250 m^3/s peak flows are higher than 1250 m^3/s for approximately 3 hours. This closure time is significantly shorter than 6 hours. Additionally the closure occurs generally while the rainfall event is still occurring, with the road returning to flood free 7 hours after the onset of rainfall. This is visually represented in attachment 1 of this document.

Based on the relationship between flow and water level at the road in this scenario, it is identified that the road is inundated for approximately 15% longer than the discharge is above 1250 m^3/s.

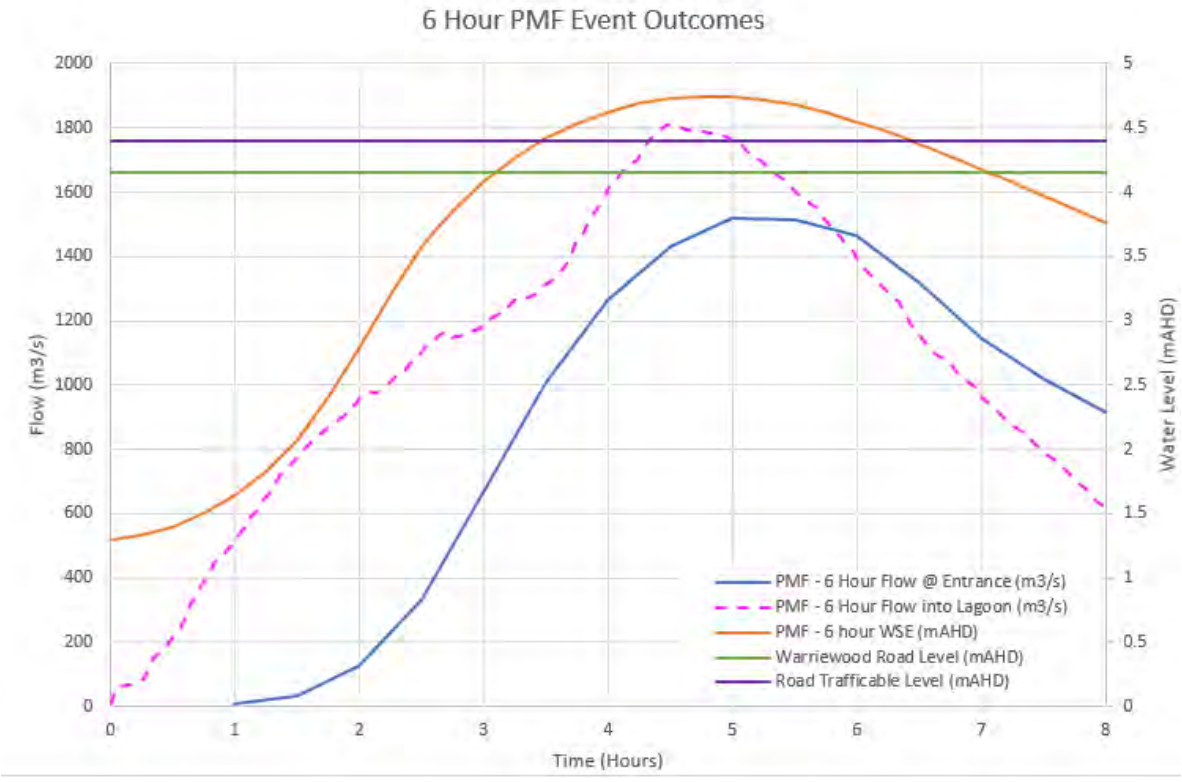


Chart 1 - 6-hours PMF Event Results

The information that is available indicates that while Macpherson Street in front of 2 Macpherson Street may not be immune from PMF flood events, in PMF flood events deemed to generate the peak water level in the area the time of closure along the road is less than 6-hours.

During the Section 34 proceedings it was highlighted that while this event may cause the peak water level, it may not cause the peak time of closure. As such, an assessment of longer duration PMF flooding has been undertaken. Note also that the discharge hydrograph peaks shown in Chart 1 indicate that there is only a 1 to 2 hours lag between peak inflow and outflow – maximum peak water level and entrance scour.

Best Practice PMP and PMF Assessments

Currently within Australia, Probable Maximum Precipitation is assessed utilising three methods:

- Generalised Short Duration Method (GSDM)
- Generalised Southeast Australia Method (GSAM); or
- Generalised Tropical Storm Method (GTSMR)

Depending on the location of the catchment, its area and the purpose of the study, there are several options for selecting the correct PMP method. These take into account such factors as seasonality, short duration/long duration requirements and method zone. To help appreciate this, a list of the methods for estimating PMP in Australia and their limits of applicability is presented on Image 1 (*Guidebook to the Estimation of Probable Maximum Precipitation: GENERALISED SOUTHEAST AUSTRALIA METHOD,* BoM, 2006)

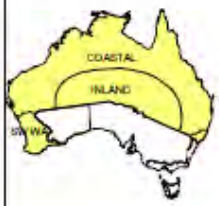
METHOD	AREA (KM²)	ZONE	LOCATION	SEASON	DURATION (HOURS)
GSDM 	≤ 1000	3 Hour	Inland and south coast	annual	≤ 3
		Intermediate		annual	4 to 5
		6 Hour	West, north and east coast	annual	≤ 6
	≤ 500	3 Hour	south of 30°S	monthly	≤ 3
		Intermediate	south of 30°S	monthly	4 to 5
		6 Hour	south of 30°S	monthly	≤ 6
GSAM 	1 to 1000	Inland	South Aust	annual	24(1) to 72
			Victoria	annual	24(1) to 72
			NSW	annual	24(1) to 96*
		Coastal	Tasmania	annual	24(1) to 72
			Victoria	annual	24(1) to 72*
			NSW	annual	24(1) to 96*
	1000 to 40,000	Inland	South Aust	annual	24* to 72*
			Victoria	annual	24* to 72*
			NSW	annual	24* to 96*
		Coastal	Tasmania	annual	24* to 72
			Victoria	annual	24* to 72*
			NSW	annual	24* to 96*
	> 40,000	Only issued on special request.			* One more (or one less) duration available on special request.
GTSMR 	up to 150,000	Inland		annual	24(2) to 96
		Coastal		summer	24(2) to 120
			minus SW WA	winter	24(2) to 96
		SW WA	SW WA	winter	24(2) to 96
West Coast Tasmania	up to 3,000		Southwest Tasmania	annual	24 to 72

Image 1 - Area, duration and zone limits for application of PMP methods in Australia (BoM, 2006)

Based on the catchment characteristics and the location, both the GSDM and the GSAM approaches are relevant to this catchment.

The GSDM is to be utilised up to and including the 6-hours rainfall event. This was previously adopted for the *Narrabeen Lagoon Flood Study* (BMT, 2013). This information is deemed accurate and has not been revised for this task. The GSDM is also used to estimate the 12 hour rainfall depth, which is not provided directly via either the GSDM or the GSAM approaches, however it is considered appropriate to estimate the depth by combining the two approaches.

The GSAM is to be utilised for durations of 24 hours and longer. For the 12-hours event the longer duration GSAM values should be utilised to inform the interpolation.

Development of Long Duration Rainfall Depths

Based on a review of current approaches, the PMP rainfall depths for the GSAM approach have been developed in accordance with the process described in *Guidebook to the Estimation of Probable Maximum Precipitation: GENERALISED SOUTHEAST AUSTRALIA METHOD,* BoM, 2006. As per Image 1, an annual assessment within the Coastal Zone has been completed. Raw depths were taken from a 55 km^2 area and the following adjustment factors applied:

- Moisture Adjustment Factor – MAF of 0.905
- Topographic Adjustment Factor – TAF of 1.35

Table 1 provides the outcomes of the estimation of PMP depths. In addition, this table provides the GSDM estimates used as part of the *Narrabeen Lagoon Flood Study* (BMT, 2013). Note values have been rounded to the nearest 5 mm. Chart 2 provides a visual representation of the values, including the interpolated 12-hours PMP estimate. Of note is that relative to the intensity of the PMP 6-hours event, the 12-hours and 24-hours event values are significantly diminished. Noting this significant drop off, events longer than the 24-hours event have not been assessed further.

Table 1 – Estimated PMP Rainfall Depths

PMP Estimation Tool	Duration (Hours)	Rainfall Depth (mm)	Rainfall Intensity (mm/hr)
GSDM	3	510	170
GSDM	4	580	145
GSDM	6	690	115
Interpolated	12	825	69
GSAM	24	1005	42
GSAM	36	1120	31
GSAM	48	1185	25

Following the development of the rainfall depths, appropriate temporal patterns have been adopted for the 12-hours and 24-hours events. The advice set out within the GSDM guidebook indicates that temporal patterns for these events should not be utilised for longer duration events. Hence, the temporal pattern for the 24-hours event has been utilised for the 12-hours interpolated event. The duration of each time-step has been halved to ensure the duration of the storm is 12 hours.

The rainfall events have then been incorporated into the XP-RAFTs model developed as part of the *Narrabeen Lagoon Flood Study* (BMT, 2013).

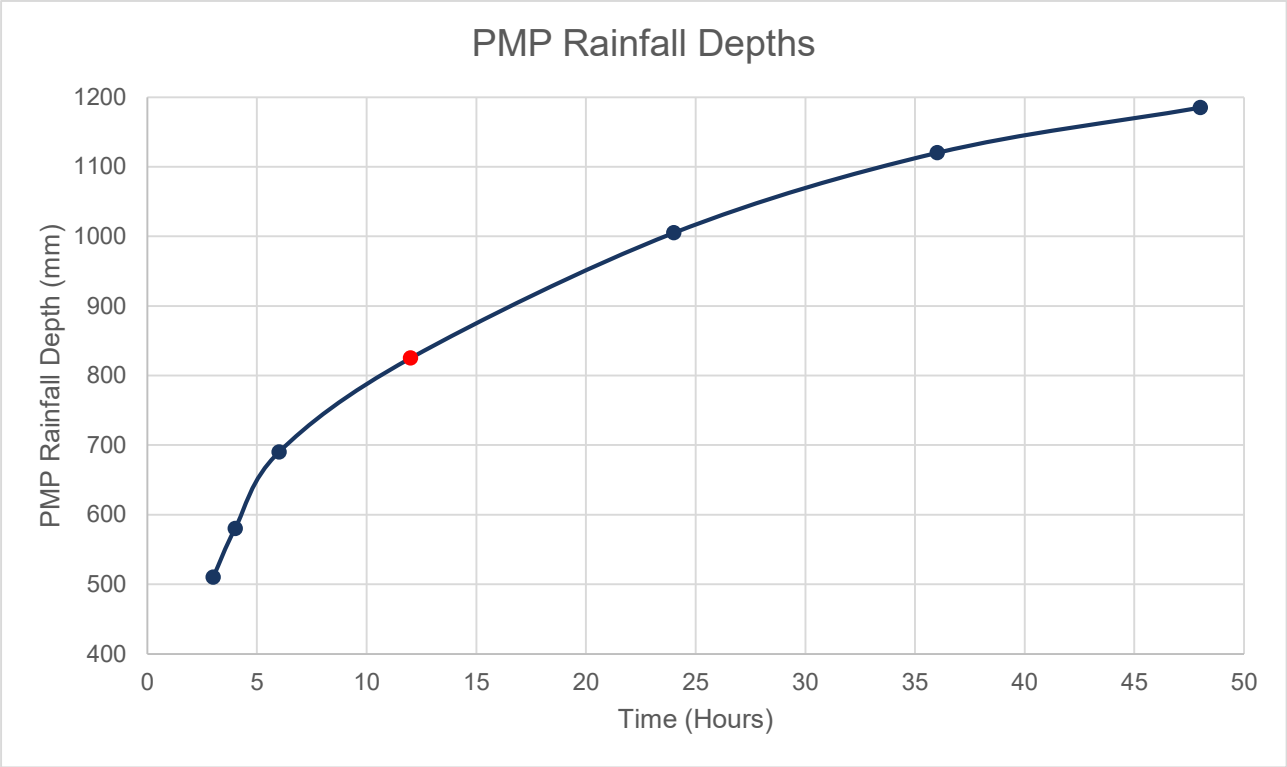


Chart 2 – PMP Rainfall Depths

Scour and Flow Capacity of the Entrance

In order to assess the potential impacts of the 12-hours and 24-hours PMF events within the lagoon, it is necessary to make some physically realistic assumptions with regard to the entrance scour and flow capacity. For the purposes of this assessment, it has been assumed that the theoretical capacity of the entrance is reached in the hydraulically modelled 6-hours PMF event. Based on this, the theoretical capacity of the entrance is approximately 1500 m^3/s – consistent with Chart 1.

Assessment Results

Chart 3 shows the outcomes of the flow assessment of the 6, 12 and 24-hours PMF events. What is immediately apparent is that the 24-hours event peak flow rate does not exceed the theoretical capacity of the outlet – that is 1500m^3/s. As such, while flooding may potentially occur in this event it is unlikely to result in a time of closure that exceeds what is predicted in the 6 hour PMF event.

In the 12-hours PMF event, the peak flow calculated is approximately 1300 m^3/s. This is 500 m^3/s lower than the recorded 6-hours PMF peak flow and 50 m^3/s higher than the peak flow recorded to cause road overtopping.

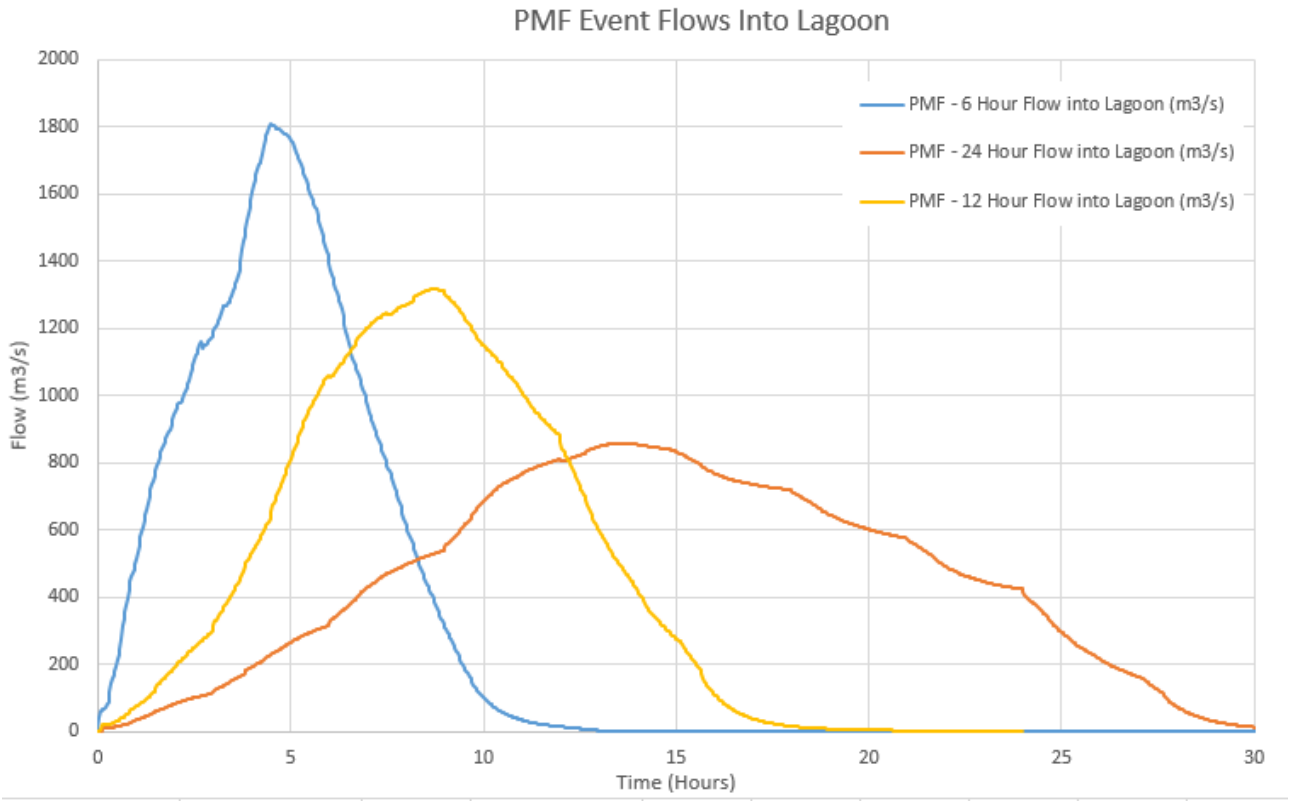


Chart 3 – PMP Event Flows

Analysis and Discussion

Based on this assessment, no PMF event of duration greater than 6-hours exceeds the theoretical discharge capacity of the outlet – 1500 m^3/s. In the 12-hours event however, the peak flow exceeds 1250 m^3/s, which, in the hydraulically modelled 6-hours PMF event was the flow rate (Flow into Lagoon), at which road closure occurs.

For the purposes of this assessment it is considered that a similar flow rate may result in road closure during the 12-hours event. It is noted that this assumption is likely conservative in nature, because the 12-hours PMF event has significantly more volume prior to reaching this peak flow. As such, it is likely that by the time the peak flow rate in the 12 hour event is experienced the entrance will be more open (greater scouring, or up to the maximum entrance opening), than at the equivalent time in the 6-hours PMF event.

A review of this flow rate, assuming that this is a flow rate that will result in overtopping of the road, identifies that, in this scenario the flow is in excess of 1250 m^3/s for a significantly shorter period. Chart 4 shows this in detail, comparing the 6-hours PMF and the 12-hours PMF results. Assuming that the water elevation response in the location is similar to that in the 6-hours PMF event (i.e. 15% longer than the peak flow above 1250 m^3/s) the 12 hour PMF event would result in the road overtopping for less than 2 hours, less than the expected inundation time present in the 6-hours PMF event.

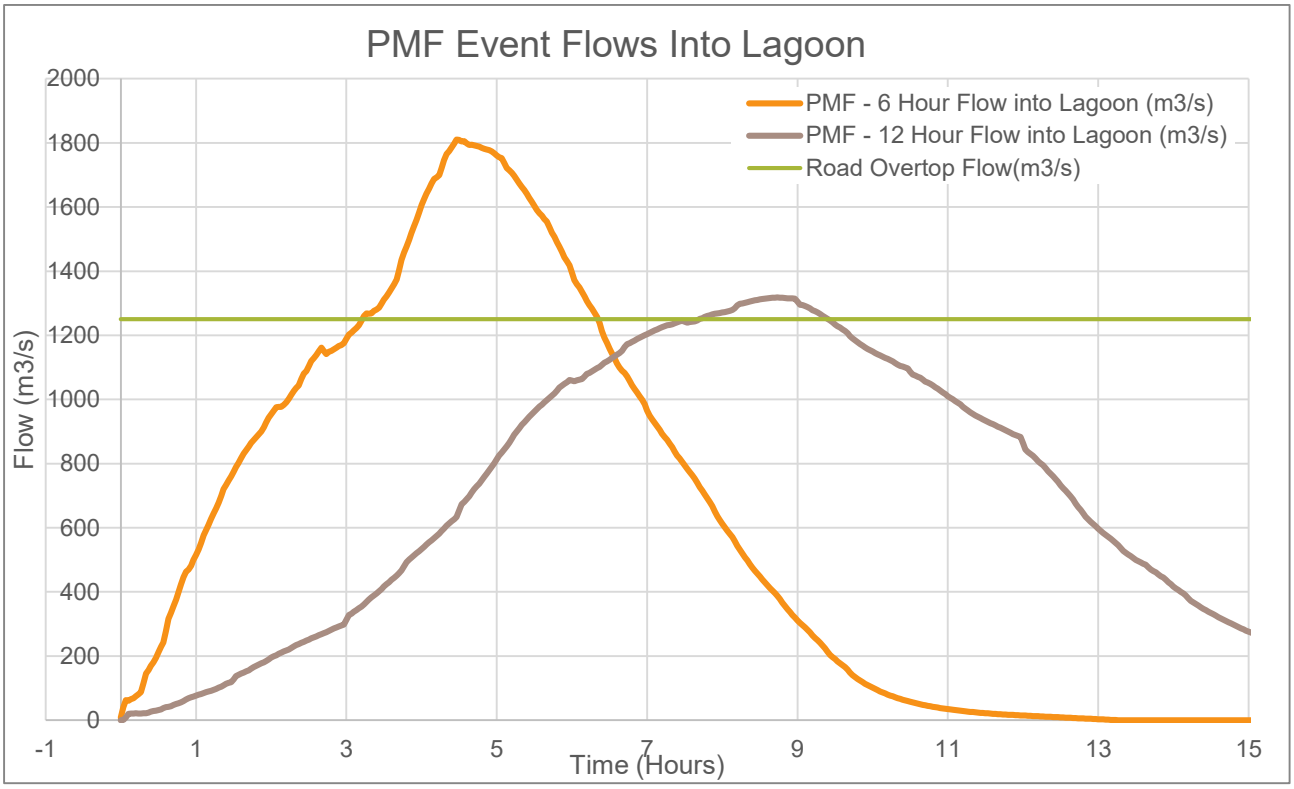


Chart 4 – PMF Event Flows v Entrance Capacity

Further Analysis

Based on feedback from Council, the aforementioned linear discussion relating the closure time of Macpherson Street in the 6-hours PMF event to the 12-hours PMF event, was not considered sufficient. A concern raised, that the period of closure may be longer in the 12-hours PMF, due to the entrance response not being comparable and by the storage in the Lagoon being non-linear, required further hydrodynamic analysis to be undertaken.

Due to limitations of the Council approved model, to confirm the response of the storage and entrance morphology in the 12-hours PMF event a Delft 3D Model, developed in an aim to replicate the Council approved model of Lagoon storage and entrance morphology response was developed.

Chart 5 provides a summary of the water levels achieved in this model. It is noted that within the Delft3D modelling environment, in the 6-hours PMF the time of closure and the peak water levels at Macpherson Street are slightly longer and higher than the Tuflow model results. Further calibration of the entrance morphologic regime within the Delft3D model would likely achieve an improved correlation to the Tuflow results. As the results are conservative with regards to both water level and time of closure however, the model is deemed to be conservative for the purposes of assessing alternative model scenarios.

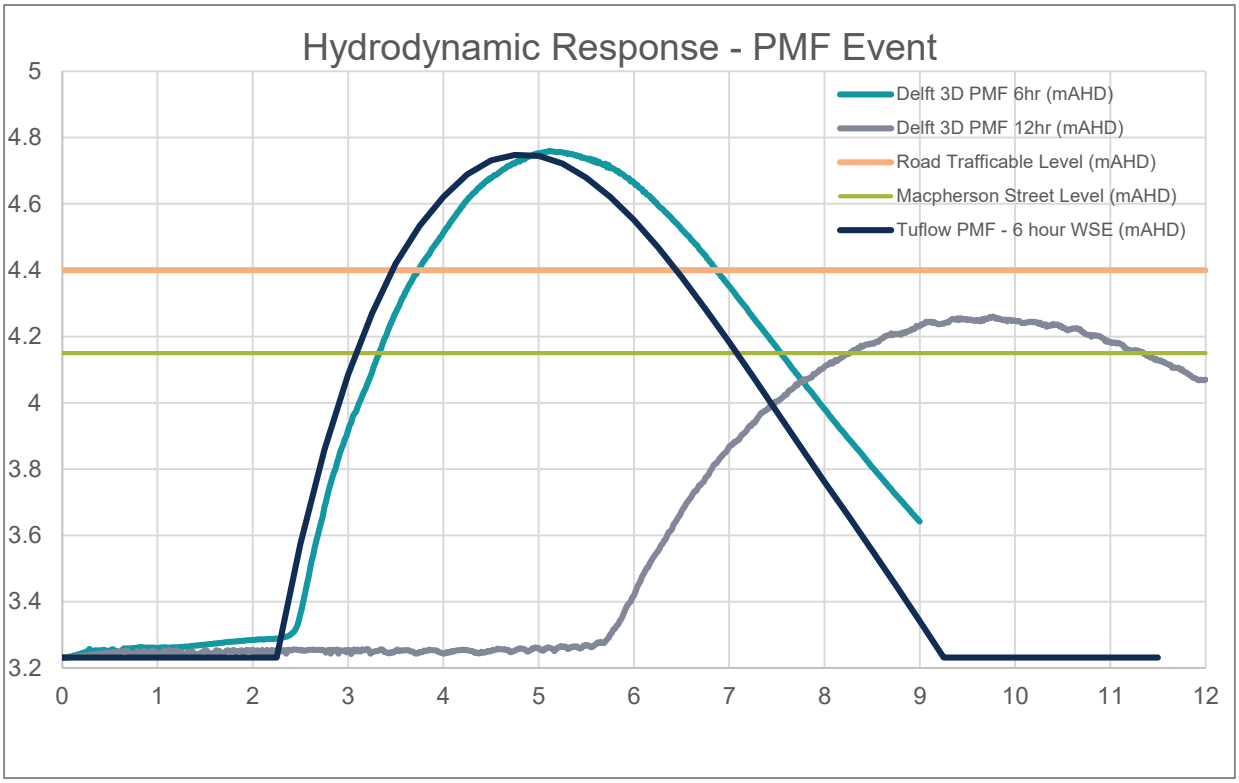


Chart 5 – PMF Water Levels – Model Response

The 12-hour PMF model was setup within Delft3D based on the hydrology discussed in previous sections. The hydrology was input into the Council approved Tuflow model (without the morphologic component active) and flows at the discharge locations of each creek into the lagoon recorded. These flows, coupled with a direct rainfall surface covering the area downstream were input into the Delft3D model as flow inputs. The 1% AEP storm tide was input as the tidal boundary condition, timed to peak at 9 hours, equivalent to the peak flow entering the lagoon. Chart 5 shows the results of this assessment.

In the 12-hours PMF within the Delft3D model the peak water level recorded at Macpherson Street is 4.25 mAHD. This is 100 mm higher than the road level and deemed trafficable. In this scenario, Macpherson Street is estimated to be inundated for less than 3 hours. This result confirms the previous assumptions utilised, and also confirms the 12-hours PMF event does not result in a time of inundation or a time of closure greater than the estimated times associated with the 6 hour PMF event.

Additional Sensitivity

In addition to confirming the assumptions within the previous assessment with regards to lagoon response, a review of the influence of the tide was undertaken. For the assessment, the tide within the Delft3D model (the 1% AEP storm surge) was shifted by 2 hours, to have the peak tide and flow offset. The change resulted in less than 1 cm of variance within the model compared to the base results, indicating the water level in the lagoon is not sensitive to changes in tide timing within the PMF flood event. This is a logical outcome as the water levels within the lagoon are over 2m greater than the peak predicted 1% AEP storm tide level.

Outcomes

Cardno has undertaken an expert review of the current PMF flood condition within Narrabeen Lagoon Catchment.

Analysis of existing PMF flood results generated within the *Narrabeen Lagoon Flood Study* (BMT, 2013) identified that under a 6-hours PMF event a period of inundation of Macpherson Street of 4 hours is anticipated. It has also been identified that the discharge capacity of the entrance is driven by water level in the lagoon and has a theoretical upper limit of approximately 1500 m^3/s. The road begins to overtop in the 6-hours PMF event when a flow into the lagoon of 1250 m^3/s is present.

Hydrologic review of longer duration PMF events identified that no event greater than 6-hours generates a peak flow rate into the lagoon in excess of the theoretical (modelled) maximum discharge rate through the entrance. In the 12-hours PMF event, flows do however exceed the flow rate at which overtopping of Macpherson Street is experienced in the 6-hours event. In the 12-hours PMF event, this flow rate is exceeded for approximately 1.5 hours, resulting in a potential inundation time of 3.0 hours. No closure period is predicted for the event. This is shorter than in the anticipated 6-hours PMF inundation time of 4 hours and closure period of 3 hours.

Further hydrodynamic review, undertaken to respond to Council concerns with regards to entrance and lagoon storage response, was completed following the hydrologic analysis. This additional analysis confirmed the assumptions made within the hydrologic review and validated the expectation that the 12-hours PMF peak flood level would not exceed the closure time experienced within the 6-hours PMF. Similarly, additional analysis of the timing of the tide relative to the peak of PMF flows confirmed the water levels experienced within the lagoon during a PMF event are not sensitive to tidal peak timing.

Based on this analysis, it is advised that in a 12-hours PMF event, and any longer PMF event, the time of closure of Macpherson Street will be less than the time of closure estimated in the modelled 6-hours PMF event.

Yours sincerely,

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Att:6-Hours PMF Time Series Imagery